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AMERICAN MACHINIST GRINDING BOOK

MODERN MACHINES AND APPLIANCES
METHODS AND RESULTS

BY

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PREFACE

The grinding machine in its various forms and the numerous grinding processes have assumed a place of such importance in the manufacture of machinery and the finishing of metal parts in general, that it has been considered desirable to bring together in the form of a reference book, such data on these machines, wheels, and methods as are likely to be of interest and service to grinder purchasers and operators, and to the men responsible for results in the grinding department.

In gathering the material published on the following pages, we have drawn liberally upon the columns of the *American Machinist*, where from time to time have appeared articles by the best known authorities upon the subject of grinding. We have also received valuable assistance from various machine and wheel makers who have very courteously supplied us with data pertaining to different phases of the subject and we hereby acknowledge our indebtedness to all who have aided us in this direction.

THE AUTHORS.

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AMERICAN MACHINIST GRINDING BOOK

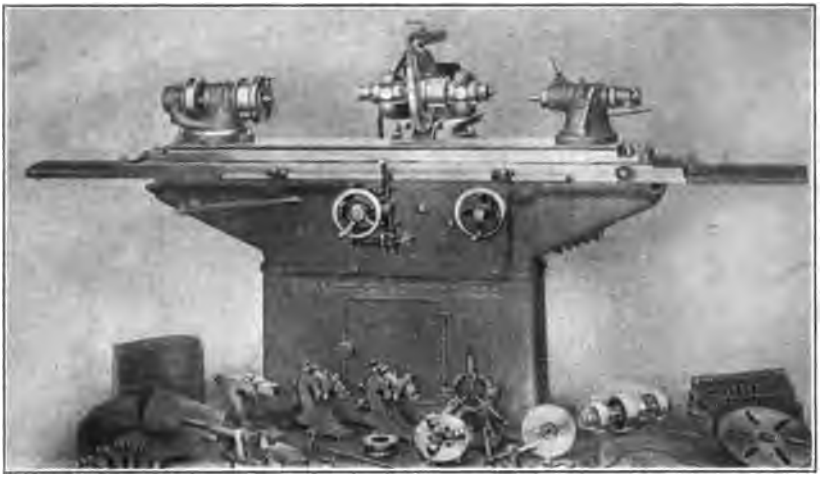


FIG. 2. BROWN AND SHARPE UNIVERSAL GRINDER.

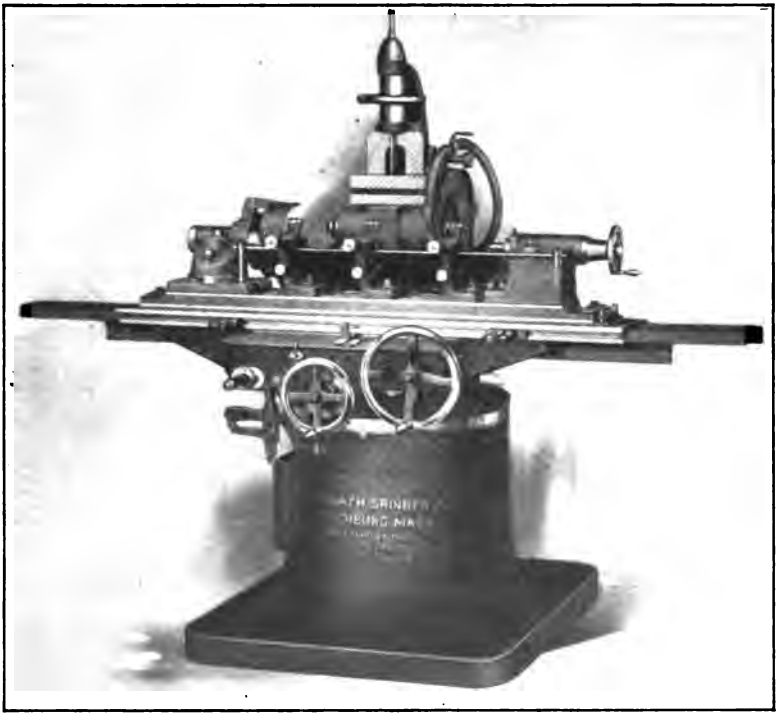


FIG. 3. BATH UNIVERSAL GRINDER.

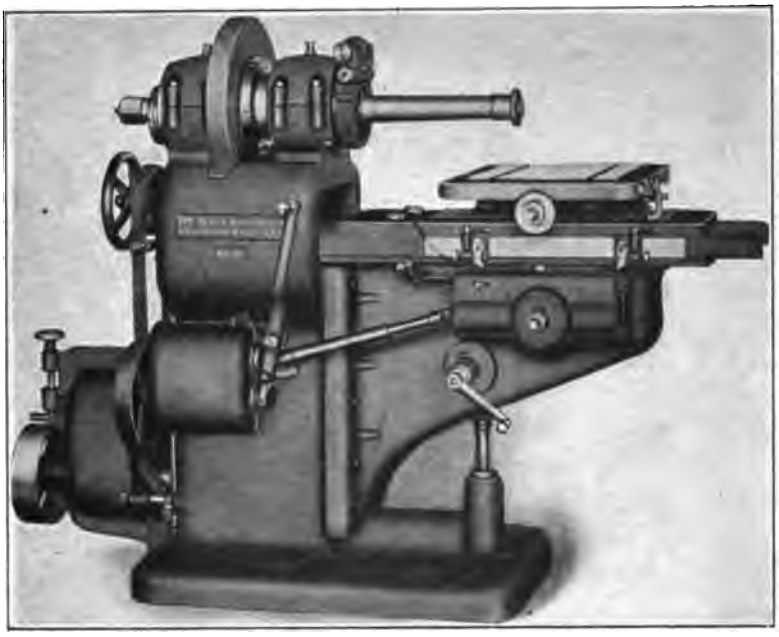


FIG. 4. HEALD CYLINDER GRINDER.

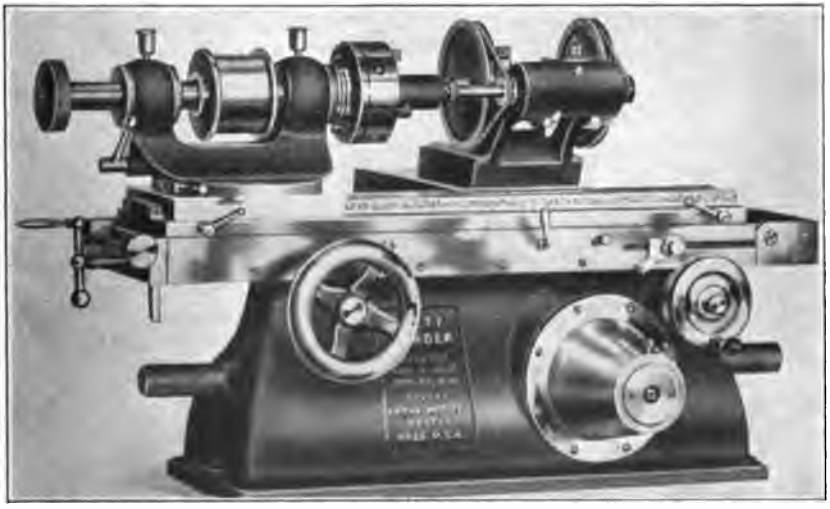


FIG. 5. RIVETT INTERNAL GRINDER.

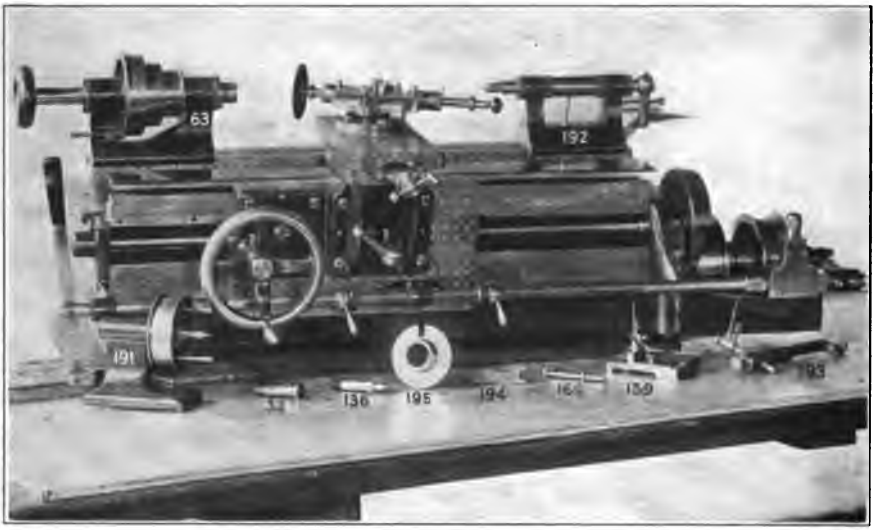


FIG. 6. HARDINGS' UNIVERSAL BEVEL GRINDER.

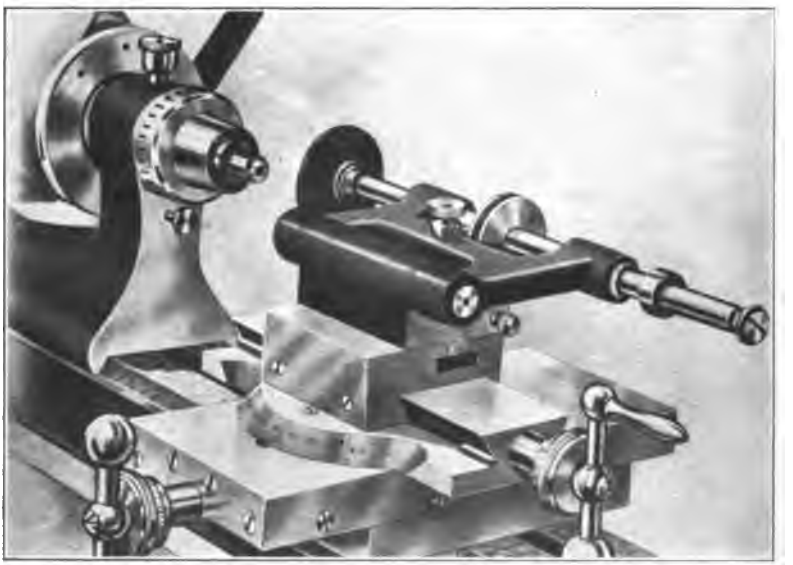


FIG. 7. AMES' TRAVERSE SPINDLE GRINDER.

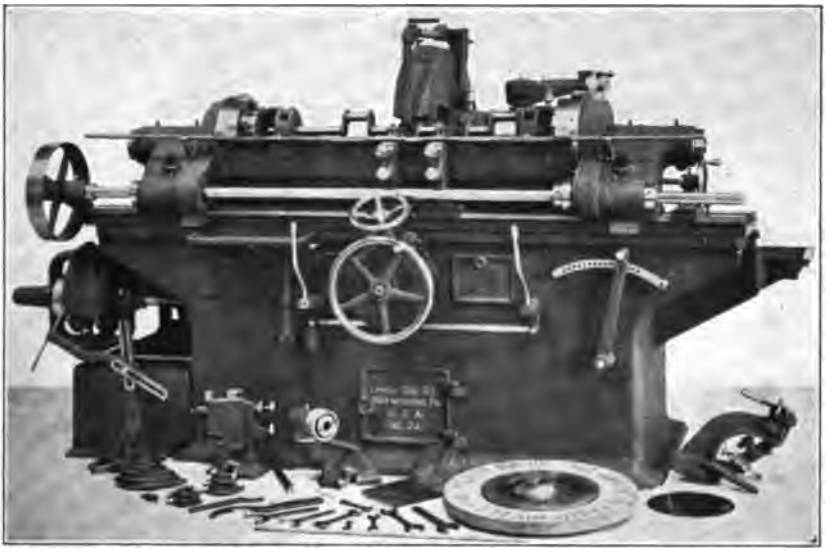
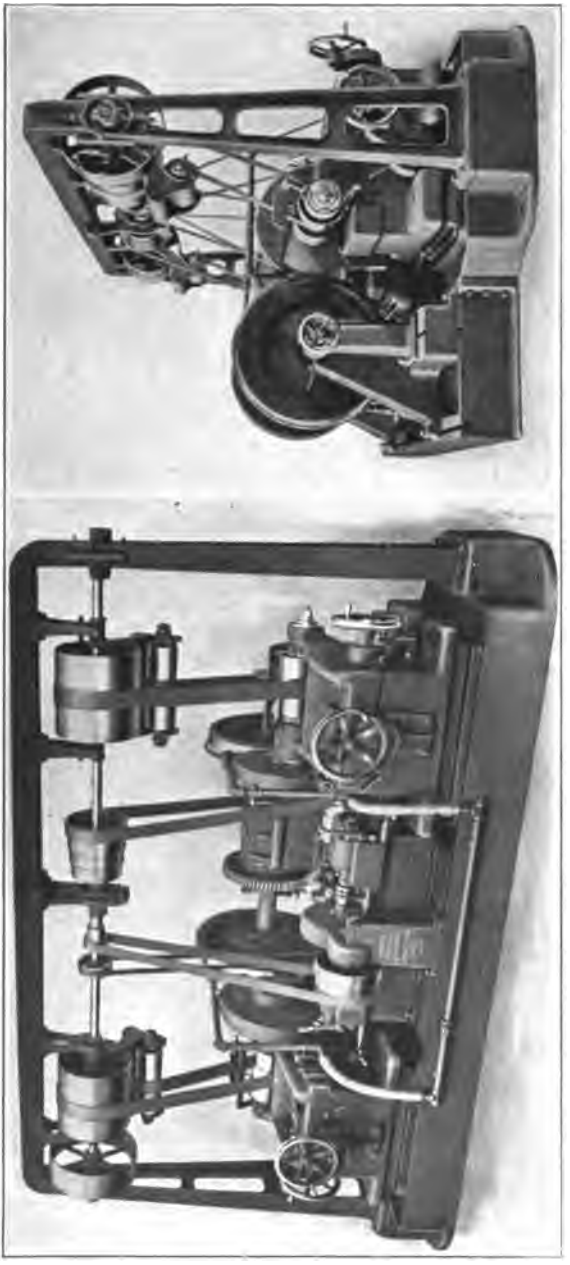


FIG. 8. LANDIS CRANK GRINDER.

FIG. 9. WORK FIXTURE ON LANDIS CRANK GRINDER.



End View.

Front View.

FIGS. 10 AND 11. NORTON 44 IN. CAR WHEEL GRINDER.

(*b*) **Universal grinders,** designed for grinding, in addition to the classes of work noted above, conical and disk-shaped pieces which may be rotated between centers or upon the face plate, and which require grinding across the face as well as upon the periphery, as in the case of a collar, a beveled blank, or a cutter. Such grinders are also used for finishing internal surfaces, both straight and taper, as the bore of a milling cutter, sleeve or ring gage. A universal grinder is illustrated in Fig. 2.

Some types of universal grinders are arranged for grinding the teeth of cutters, reamers and tools generally, in addition to accomplishing the operations outlined above. They may also be used for surface grinding. A machine of this type is the universal grinder in Fig. 3.

(*c*) **Internal grinders,** for finishing the inner surfaces of bushings, gears, gages, sleeves, etc. One specialized form of the internal machine is the cylinder grinder extensively used in automobile factories. One make of cylinder grinder is shown by Fig. 4. Another type of internal grinder is represented by Fig. 5.

(*d*) **Bench precision and traverse spindle grinders,** small high-speed machines for extremely accurate operations on light, delicate work, in tool rooms, watch shops, and other places. Grinders of this general nature, but with special features, are used extensively in finishing ball races, and various other accurate parts required in large quantities. A universal grinder for small precision work is shown in Fig. 6 with a traverse spindle rest on the cross slide. Another traverse spindle grinder is shown in Fig. 7.

(*e*) **Miscellaneous,** including crankshaft and camshaft grinders developed particularly for operations on such parts for gasoline engine and similar work; roll grinders, for finishing calendar, milling, and other rolls; chucking grinders, a recent development in which three-wheel spindles are provided for external and internal operations on all kinds of cast iron and steel parts, whether hard or soft; pulley grinders, for finishing pulleys, flat or crowned, from the rough; car-wheel grinders for grinding wheels on their axles, etc. A crank grinder is represented by Figs. 8 and 9; a car-wheel machine by Figs. 10 and 11. The chucking grinder is shown in Figs. 42 and 46.

GROUP 2

MACHINES FOR GRINDING PLANE SURFACES

Group 2 includes the following machines:

(*a*) **Horizontal surface grinders,** equipped with a plain wheel on a horizontal spindle with the work carried under the edge of the wheel, usually by a reciprocating table, though in certain types a rotating table is employed. A well-known machine in this group is the planer type grinder, Fig. 12, so called because of the general resemblance to a planer, particularly in the

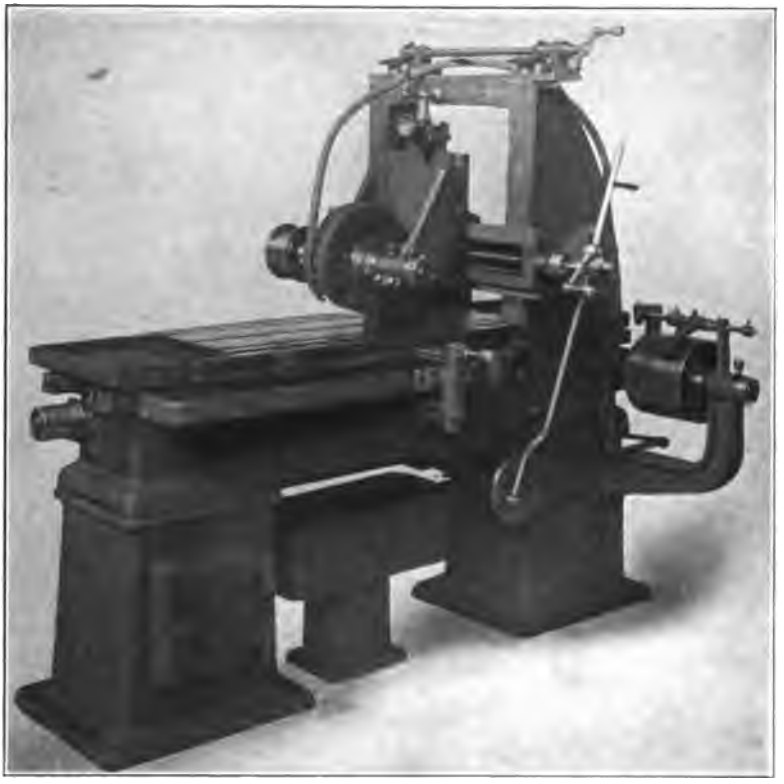


FIG. 12. SPRINGFIELD MANUFACTURING CO.'S PLANER TYPE SURFACE GRINDER.

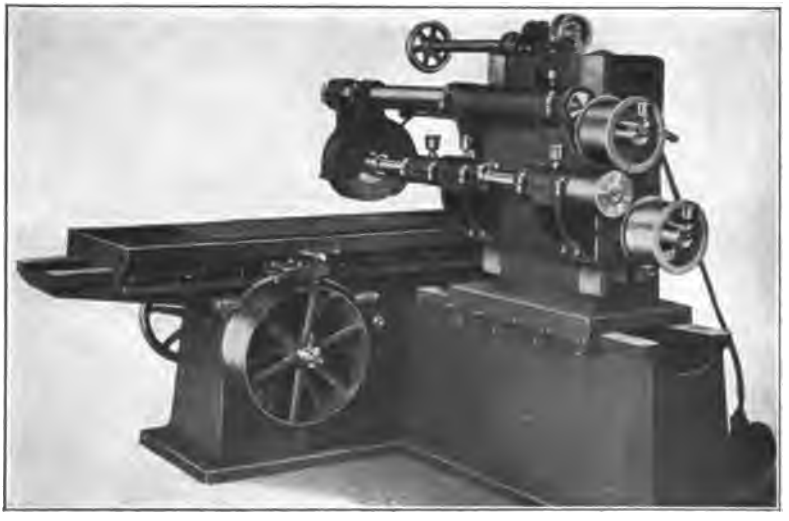


FIG. 13. SAFETY EMERY WHEEL COMPANY'S OPEN-SIDE SURFACE GRINDER.

case of the platen and cross rail which carries the horizontal wheel head. An open-side design of grinder which will handle very wide work is represented in Fig. 13. Smaller machines of the horizontal spindle type, like Fig. 14 for example, are commonly used in tool-rooms for grinding punches, dies and various other tools and accomplishing much other work of similar character. In its simplest form, the tool-room surface grinder has a plain table without power feed across which the work is moved by hand under the wheel.

(*b*) **Vertical surface grinders,** equipped with a cup wheel mounted on a vertical spindle, under which the work is carried by a reciprocating or a rotating

FIG. 14. BROWN AND SHARPE SURFACE GRINDER.

table so that the surface is in contact with the end of the grinding wheel. (See Fig. 16.)

(*c*) **End, edge, or face grinders,** horizontal spindle machines using a ring wheel which operates with its end against the surface of the work, as in Fig. 17. Such machines in one form or another are used for grinding edges and sides of castings, and for grinding machine knives, etc., as in Fig. 18. The work is either carried to and fro by a reciprocating table or remains stationary while the wheel head itself is traversed past the work. Knife grinders are also adapted for using disk wheels.

(*d*) **Disk grinders,** surfacing machines using as an abrading medium, a metal disk to the face of which a circular abrasive sheet is fastened. Such

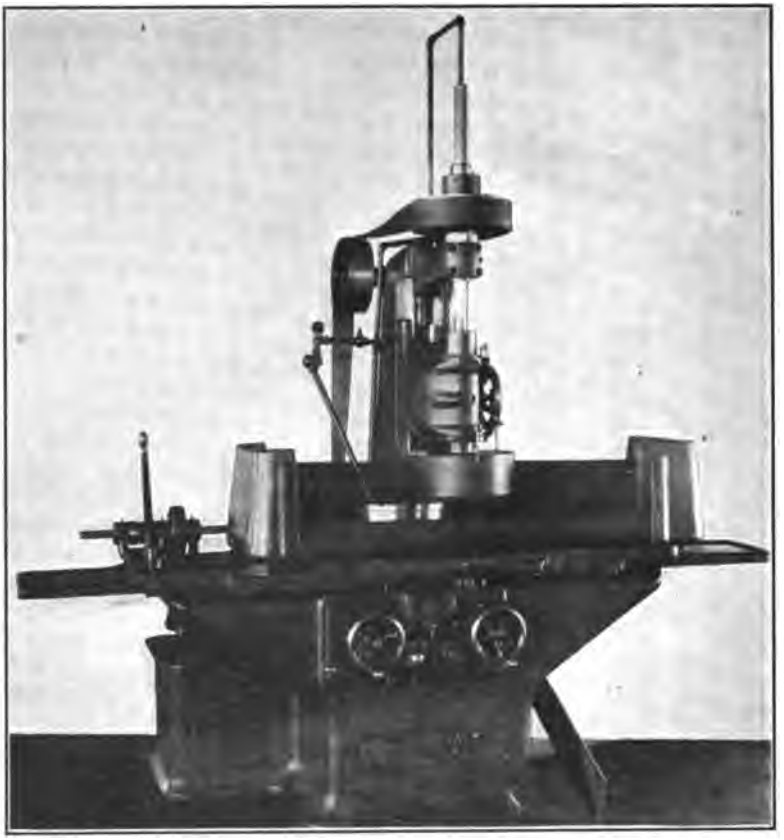


FIG. 16. PRATT AND WHITNEY VERTICAL SURFACE GRINDER.

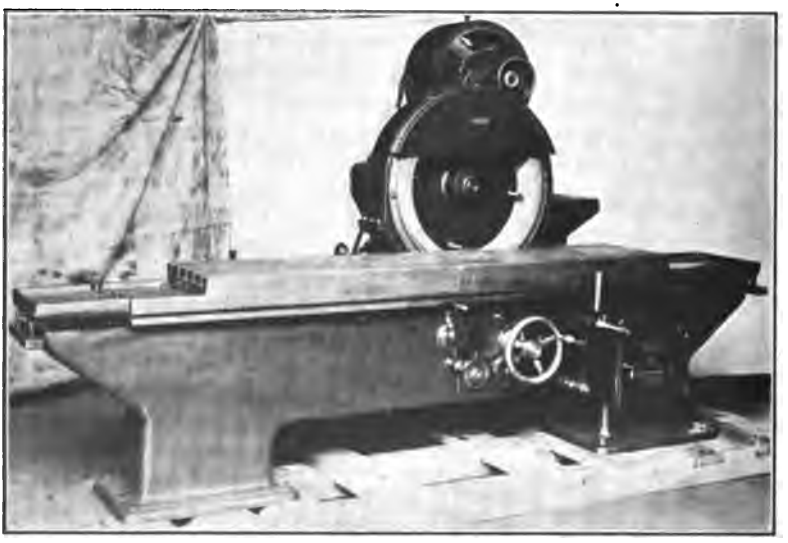


FIG. 17. DIAMOND FACE GRINDER.

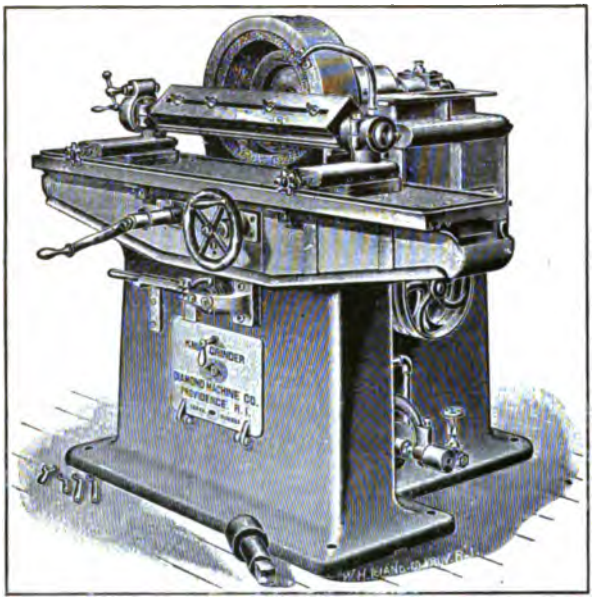


FIG. 18. DIAMOND KNIFE GRINDER.

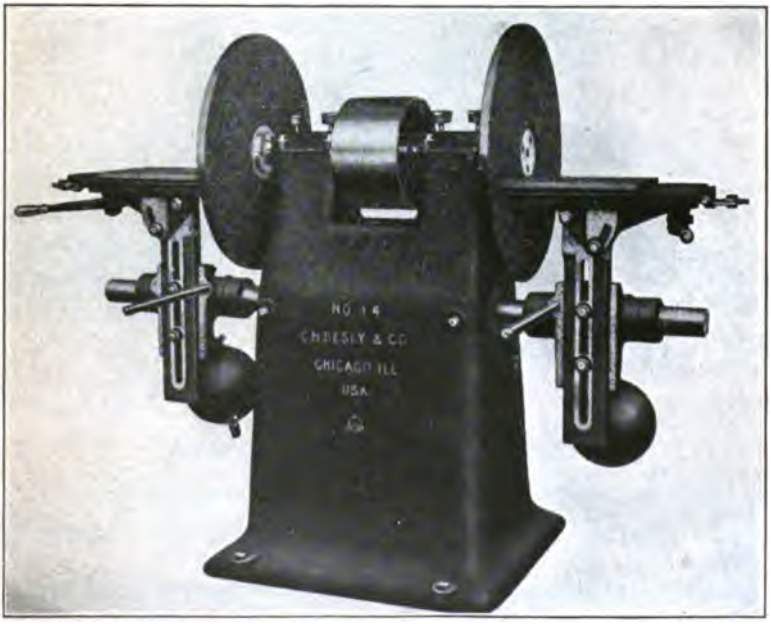


FIG. 19. BESLY SPIRAL DISK GRINDER.

grinders are extensively employed in facing all sorts of castings, and for surfacing material of various kinds that can be brought into contact with the disks. One design is shown by Fig. 19.

(*e*) **Belt grinders or grinder belts,** these are operated either vertically or horizontally, and are covered with abrasive material for finishing flat pieces or work requiring one or more flat faces. One of these is shown in Fig. 88.

(*f*) **Miscellaneous,** including piston ring grinders with rotary table, as in Fig. 20, for finishing the parallel faces of piston rings; disk grinders for finishing

FIG. 20. WALKER PISTON RING GRINDER.

the faces of flat, concave or convex disks. Vertical and horizontal lapping machines using disks charged with fine abrasive are also made for finishing flat surfaces smoothly and accurately.

GROUP 3

CUTTER, TOOL AND DRILL GRINDERS

The machines in this group are mainly for keeping tools sharp and in condition for working properly. Under this classification are included the following grinders:

(*a*) **Plain cutter grinders,** primarily designed for sharpening milling cutters and similar tools; in some designs the plain machine is converted into a universal cutter and tool grinder by the addition of certain attachments.

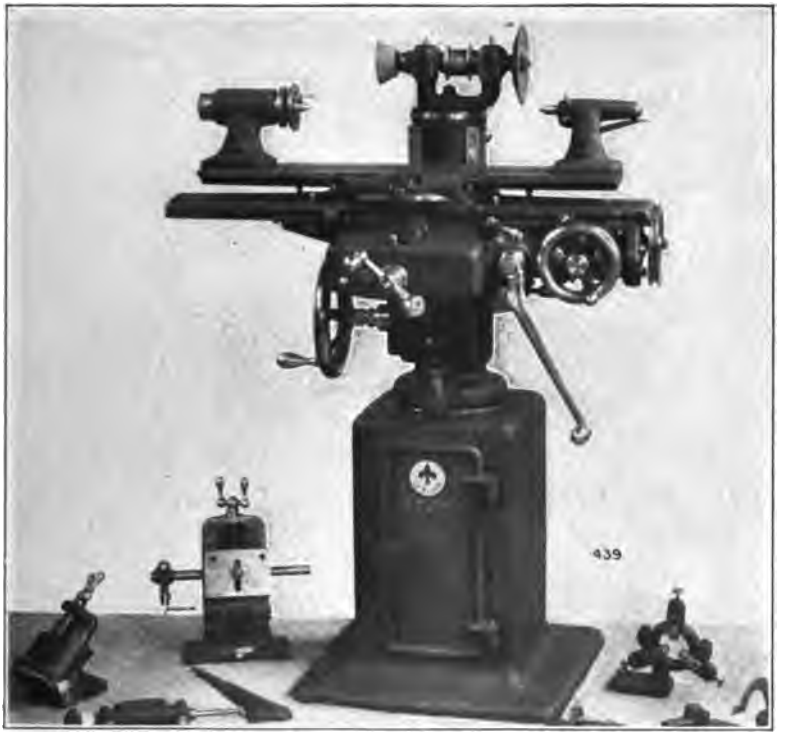


FIG. 21. LE BLOND UNIVERSAL CUTTER AND TOOL GRINDER.

FIG. 22. SAFETY EMERY WHEEL CO.'S WET TOOL GRINDER.

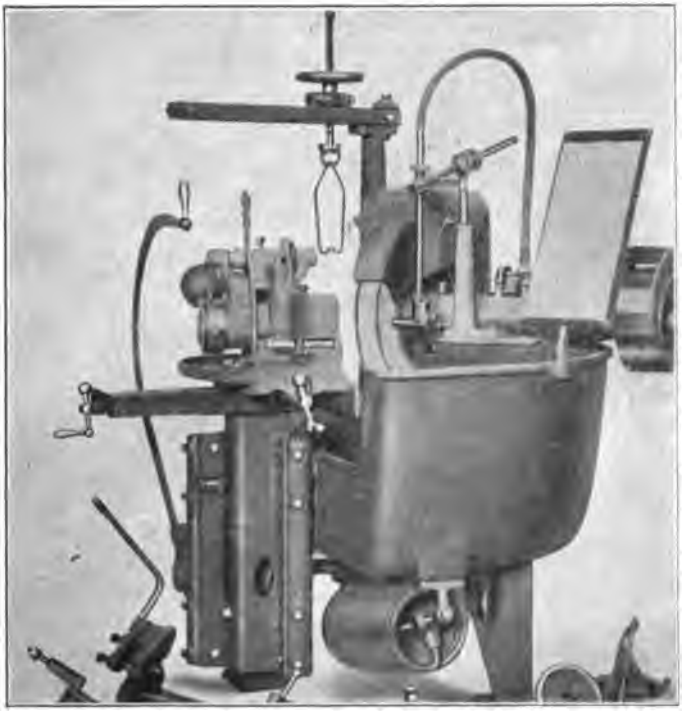


FIG. 23. SELLERS UNIVERSAL TOOL-GRINDING AND SHAPING MACHINE.

(*b*) **Universal cutter and tool grinders,** adapted for sharpening all kinds of milling cutters, reamers, saws, taps, hobs, etc., and, as already indicated, suited to a variety of cylindrical and surface grinding operations, such as are necessary in finishing bushings, mandrels, small shafts, spindles, straight-edges, knives, plates, etc. A machine of this type is shown in Fig. 21.

(*c*) **Tool grinders (for lathe and planer tools),** consisting in the simplest form of a wet or dry bench grinder or of a wet grinder stand and wheel for hand sharpening of cutting tools. For example, see Fig. 22. A highly devel-

FIG. 24. AMERICAN DRILL-GRINDING MACHINE—HEALD MACHINE CO.

oped type of tool grinder receives all kinds of lathe, planer and shaper tools as they come in the rough and shapes them accurately to predetermined forms, grinding top, front and sides to the exact contour and degree of rake and clearance desired. Fig. 23 illustrates a grinder of this character.

(*d*) **Drill grinders,** designed for sharpening twist drills and for this purpose provided, as in Fig. 24, with an oscillating holder with V-block to receive the drill and allow its lip to be passed across the side of the wheel with an angular, swinging motion which gives the desired clearance at the point for cutting. Provision is made for securing equality of length and uniformity of angle and clearance for the two lips of the drill.

GROUP 4

CENTER GRINDERS AND PORTABLE APPARATUS FOR TOOL POST AND OTHER OPERATIONS

(*a*) **Center grinders,** used in the lathe for grinding the live center to the correct angle, the wheel spindle being driven from the face plate, from an overhead drum, or by a small motor. One of these in operation is represented by Fig. 25.

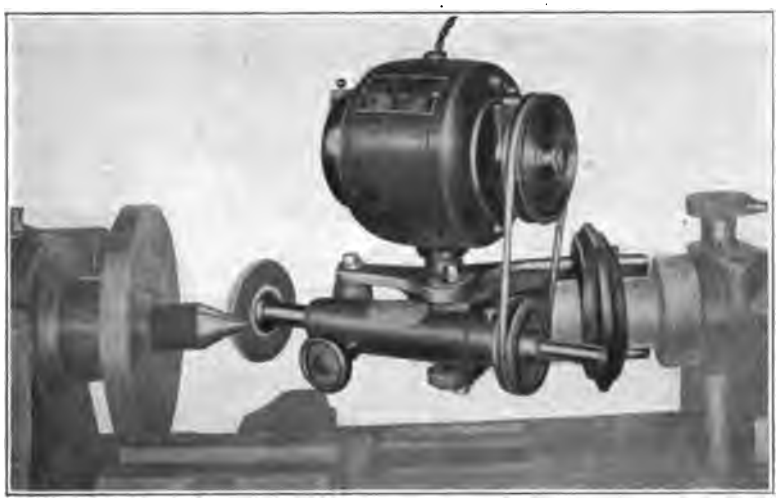


FIG. 25. MOTOR-DRIVEN CENTER GRINDER.

(*b*) **Portable electrical grinders,** portable machines, usually with motor-driven wheel spindles, for use in the engine lathe tool post for finishing cylindrical work, and also used in the shaper or planer tool post and on machine tables, for special grinding operations. Typical illustrations are given in Figs. 26, 27, and 28.

(*c*) **Portable machines,** with some form of pulley drive or with flexible-shaft drive, as in Figs. 29, 30 and 31, for grinding drop-forge dies, metal patterns, irregular blanking dies, and for external and internal operations on other bench-work.

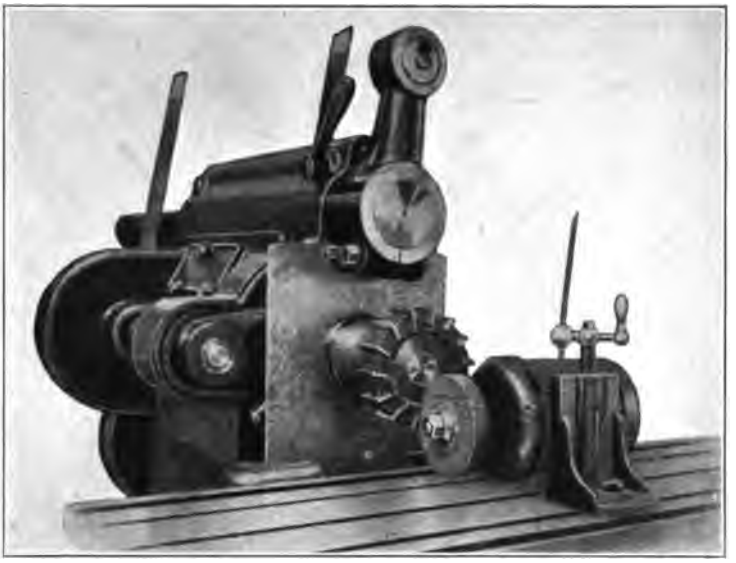


FIG. 26. SHARPENING MILLING CUTTER WITH U. S. PORTABLE ELECTRICALLY DRIVEN GRINDER.

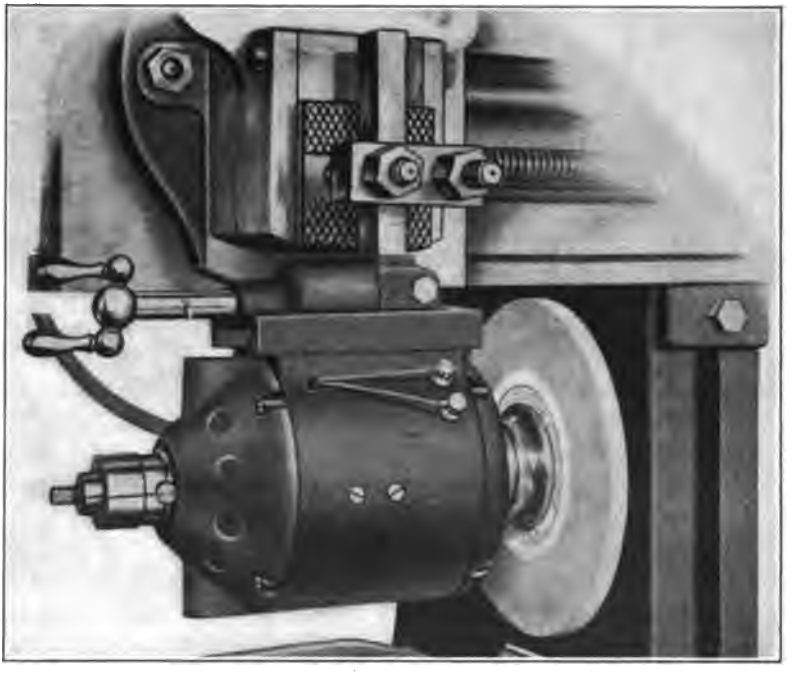


FIG. 27. HISEY-WOLF PORTABLE ELECTRIC TOOL POST GRINDER USED IN THE PLANER.

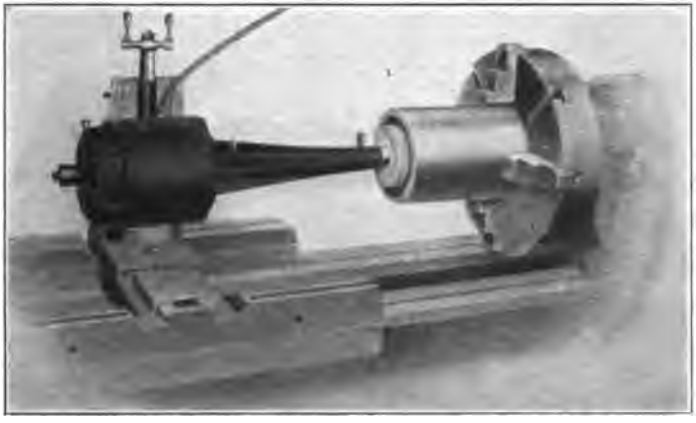


FIG. 28. U. S. PORTABLE GRINDER ON INTERNAL WORK.

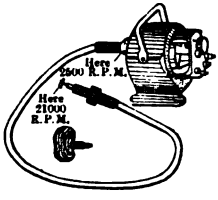


FIG. 29.

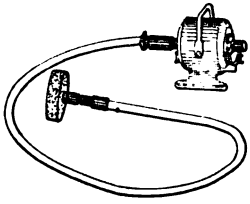


FIG. 30.

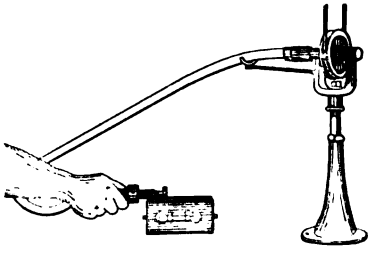


FIG. 31.

COATES OUTFITS FOR GRINDING DIES, ETC.

GROUP 5

BENCH, FLOOR AND SWING-FRAME GRINDERS FOR SHOP AND FOUNDRY

Under this head may be grouped a great variety of simple grinding apparatus for smoothing castings, surfacing bosses and pads, grinding off scale and fins,

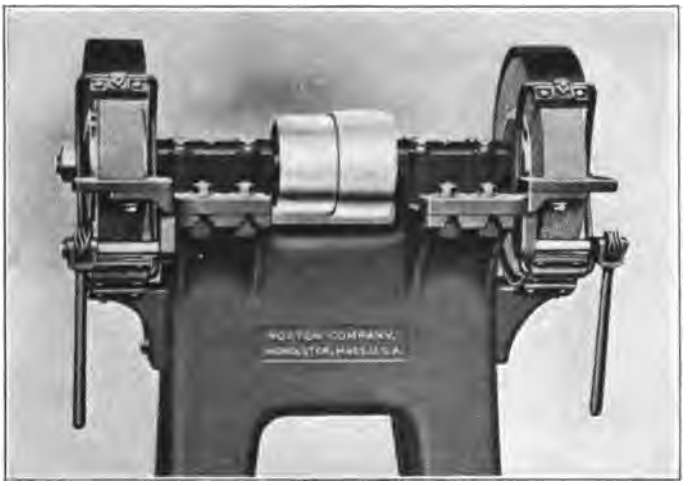


FIG. 32. NORTON FLOOR GRINDER WITH PROTECTION HOODS.

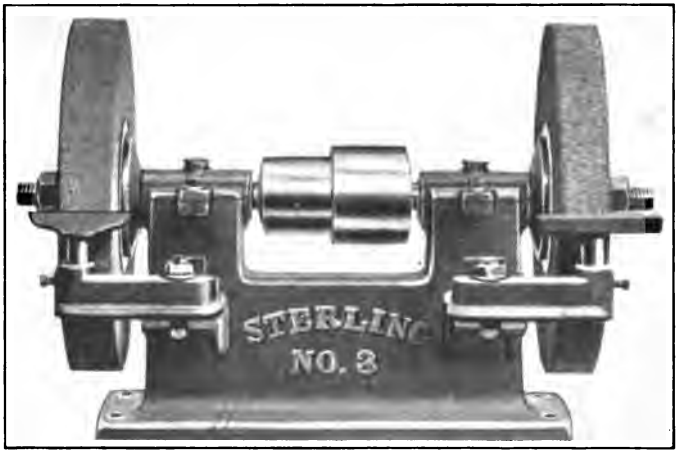


FIG. 33. STERLING BENCH GRINDER.

rounding corners and performing an endless number of similar operations, where the casting, forging, or other piece can be held in contact with the wheel without the necessity of mounting it upon a power actuated table.

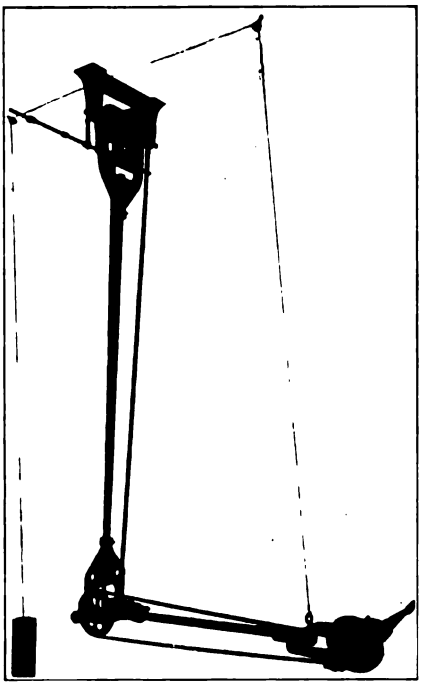


FIG. 34. STERLING SWING FRAME, GRINDING AND POLISHING MACHINE.

FIG. 35. U. S. SUSPENDED ELECTRICALLY DRIVEN GRINDER.

(*a*) **Bench and floor grinders** are usually made up as in Figs. 32 and 33, of a plain stand with a simple horizontal spindle at the top carrying a wheel at each end. The spindle may be either belted or direct motor driven.

Machines of quite similar character, with abrasive and buffing wheels are used extensively in polishing and buffing work for plating. They are commonly known as polishing jacks, polishing stands, buffing heads, etc.

(*b*) **Swing-frame grinders** are suspended in such manner as to enable the operator to pass the wheel over castings of almost any form or size. Fig. 34 is an example. Fig. 35 shows a suspended grinder for castings, which has a wheel mounted on the motor shaft. A portable outfit with flexible shaft drive is seen in Fig. 36.

FIG. 36. COATES PORTABLE SNAGGING OUTFIT.

CHAPTER II

SOME RECENT DEVELOPMENT IN GRINDING MACHINES

The past few years have witnessed many interesting developments in the design and construction of grinding machines of various types and in the general practice of grinding as well. This period has brought forth a number of novel grinders and various important improvements have been made in the older machines during that time.

As it is the purpose of this book to show methods of grinding and to describe the care of wheels, machines and work, rather than to present details of grinder construction and design, it is obviously impossible to illustrate all of the different makes of machines of importance in the grinder field. Of the numerous types of grinders in service, a few of which have been developed in the past 3 or 4 years and which contain unusually novel and radical features, have been selected for illustration and brief description in this chapter.

THE PRATT AND WHITNEY AUTOMATIC SIZING GRINDERS

The machine illustrated by Figs. 38, 39, 40 and 41, is an automatic sizing grinder built by the Pratt & Whitney Company, Hartford, Conn., for cylindrical and taper work. This grinder is provided with a sizing device and automatically controlled feed by means of which duplicate parts may be automatically finished to uniform size regardless of the wear of the wheel during the progress of the work. When the mechanism is once set for the first piece ground, the operator has simply to remove the piece when completed, place another piece between the centers and start the feeding mechanism, which continues to advance the wheel to the work until the latter is ground down to the required size, when the feed is automatically thrown out of action. The ingenious mechanism for accomplishing this important operation of bringing the work accurately to size, without the necessity upon the part of the operator of calipering the diameter and feeding the wheel slide to compensate for any wear of the wheel prior to the final finishing passes, provides for the taking of coarse feeds until the work is nearly to size, when a very fine feed is automatically thrown in for the finishing operation.

GENERAL FEATURES OF CONSTRUCTION

Figure 38 is a general view and shows the grinder as a whole, with the simple driving parts mounted directly on the machine and so arranged that

all complications in overhead works are done away with and replaced with a simple tight and loose pulley countershaft.

The work table is provided with a V and a flat way on the bed, and has a T cross-section with a deep rib to which the rack is fastened. The slide which is mounted on the top of the table is secured by a clamp at each end and swivels at the center. At the right-hand end is provided a micrometer adjusting device for taper grinding.

The head and foot stocks are of goose-neck pattern allowing the guard to pass outside the work placed between them. The work revolves on dead centers and the work driver is gear driven. The foot-stock spindle is manipulated with a lever at the top. When spring tension is not desired on the work, a clamp

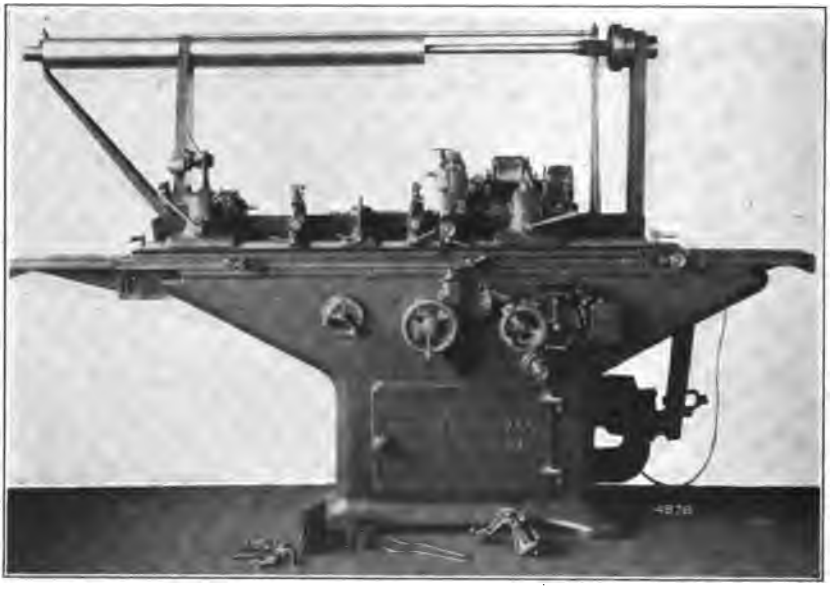


FIG. 38. PRATT AND WHITNEY AUTOMATIC SIZING GRINDER.

is provided to clamp the spindle in any position desired. The spring pressure is also regulated by turning the nurled knob at the rear end of the foot stock. There are four work speeds.

The table is reciprocated by means of rack and mechanism operated from a gear box giving instantly six changes of table feed entirely independent of either wheel or work speed. The reversing mechanism is controlled by the table dogs and will reverse the table within 0.001 in., thereby making it possible to grind close to a shoulder.

The wheel spindle has two rates of speed and is of hardened and ground tool steel running in bronze, adjustable boxes which are dust- and water-proof, and self-oiling.

THE AUTOMATIC SIZING DEVICE

This device is illustrated in Figs. 39 and 40. The wheel feed proper may be operated entirely independent of the automatic sizing device. Transverse movement of the wheel slide is obtained through a large screw and nut and is accurately controlled by the feeding device through encased spur gearing located on the back of the machine. The feed may be operated either by hand or automatically, with or without the sizing device. The feed hand wheel is provided with accurate graduations, also an adjustable stop to assist in controlling the slide when operated by hand. Both the roughing and finishing automatic feeds are obtained by means of separate feed pawls operating upon a ratchet. These feed pawls are entirely independent of one another, but derive their rotating action from the same connecting lever. A feed movement of from 1/2 to 12 notches is obtainable by means of conveniently located adjusting screws, which reduces the diameter of the work from

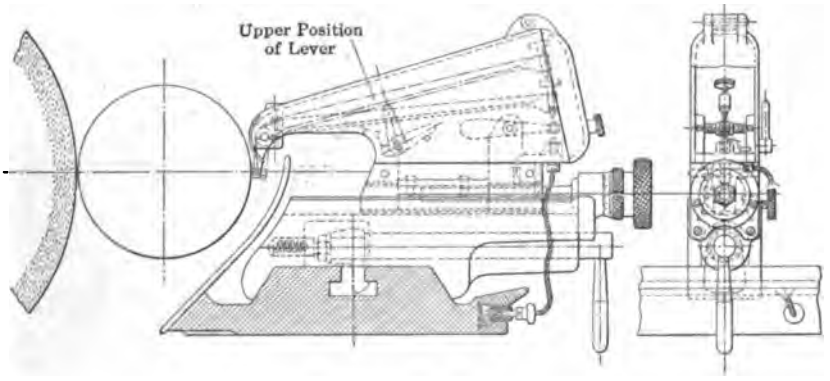


FIG. 39. CONSTRUCTION OF AUTOMATIC SIZING DEVICE, ON PRATT AND WHITNEY GRINDER.

0.000125 to 0.003 in. The finishing pawl is made double to permit the taking of a 1/2-notch feed when desired. The automatic feed may be instantly engaged or disengaged by a conveniently located knob or by the automatic sizing device.

Say that roughing pawl *A*, Fig. 40, is set to feed eight notches, finishing pawl *B* to feed one notch, after which disengager *C* is located so as to disengage the roughing pawl within 0.001 of the finished size. In setting the roughing pawl disengager it is important that set-screw *D* should come against stop *E* on the disengager, which has the effect of automatically maintaining the relation between the roughing and finishing pawls; thus, the amount left for the finishing feed always remains constant regardless of the wear of the wheel. After the roughing pawl has been disengaged, the finishing pawl continues to feed until disengaged by the automatic sizing device in the following manner: Magnet *F*, which is operated by a dry battery and whose one

function is to disengage the fine feed pawl when the work has been reduced to the desired diameter, forms part of the construction. The electrical circuit is carried through the automatic sizing device, the magnet remaining inoperative due to a break between points *H* and *G* in the automatic sizing device. The downward movement of the sizing lever *I*, caused by the reduction of the work, completes the circuit by forcing points *G* and *H* together when the work has been reduced to the required diameter. The completed circuit has the desired effect of instantly disengaging the fine feed pawl by means of the magnet having become operative and released the disengaging trip *J*. The

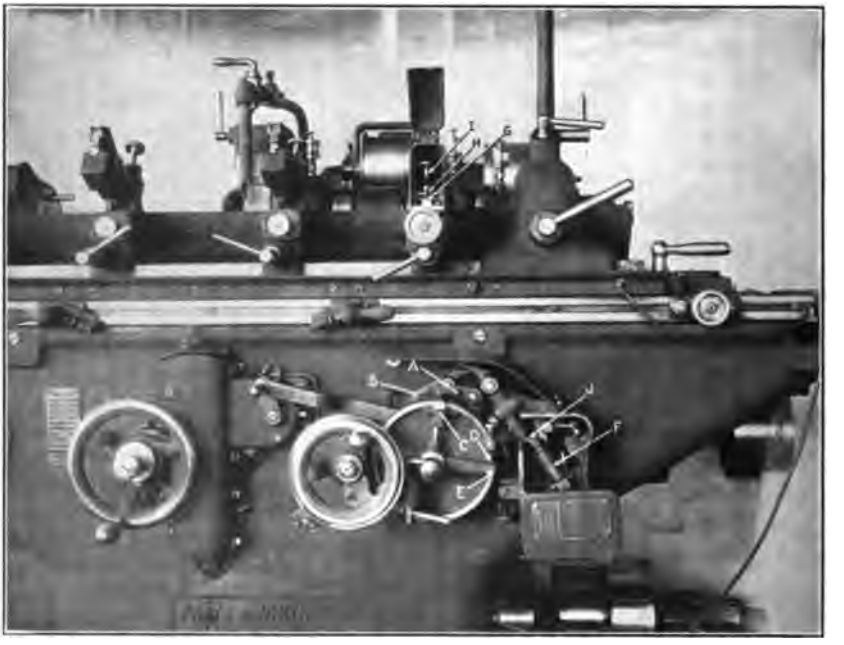


FIG. 40. PRATT AND WHITNEY CO. WHEEL FEED MECHANISM AND SIZING DEVICE.

sizing lever is then removed to its upper position while new work is being placed in the machine. In setting this device it is only necessary to grind a piece to the required size, after which the proper adjusting of the sizing lever is promptly determined by means of the micrometer screw and dial which govern the transverse adjustment of the device, also an adjusting screw is provided in the sizing lever for very delicate adjusting.

As will be noted by the half-tone and also in Fig. 39 the device is self-contained and is of simple nature. It may be located at any position on the table, as an encased wire with suitable connecting places is provided on the front of the table. All the wires are either encased or insulated in a manner

to make short circuiting impossible and the voltage is so low that the dry battery used will last a long time without being replaced.

OTHER FEATURES OF INTEREST

Among the other features of interest and value may be noted the provision for pumping an abundance of water from a large tank at the rear of the machine; the wheel truing and centering devices, both of which are easily located on the table without disturbing other attachments; the system of back rests which are of the automatic positive feeding type.

The construction of the rests will be seen upon examination of Fig. 41.

FIG. 41. PRATT AND WHITNEY BACK REST.

In operation the back-rest shoe automatically follows up and correctly supports the work throughout the grinding operation without yielding, at a pressure easily governed to meet any requirement. The proper relation between the work and the supporting shoe is maintained by the downward movement of lever *A* which raises the shoe holder with the shoe as the work is reduced. The downward movement of lever *A* causes roll *B* to advance, the roller path being on a suitable angle to permit the back pressure to be taken by the roll without slipping. The pressure is governed by adjustable weights located upon this lever. When the work has been reduced to the required diameter the back-rest shoe is withdrawn from the work by the roll and lever being returned and held in the upper position by clamp *C*. Both radial and vertical adjustments are provided by means of adjusting screws. The back rest may be very easily removed from the bed by a slight inward pressure on the eccentric binder which serves to release the binding clamp.

The back-rest shoes are made and located so as to give the maximum support to the work. The shoes with each rest are suitable for work from

1/4 in. to 2 in. diameter. The machine illustrated has capacity for grinding work up to 6 in. diameter by 48 in. long. Another size built has a capacity of 4 by 30 in. Both sizes use 12-in. wheels.

THE BRYANT CHUCKING GRINDER

A new type of machine brought out by the Bryant Chucking Grinder Company, of Springfield, Vt., is illustrated by Figs. 42 to 46.

This is such a departure from the usual form of grinding machine that an outside view conveys little idea of either its operation or purpose. It is called

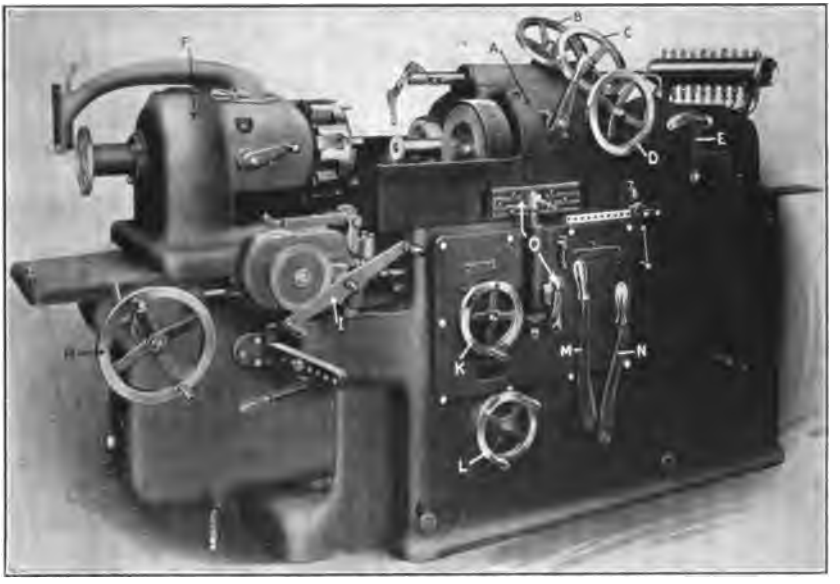


FIG. 42. GENERAL VIEW OF BRYANT CHUCKING GRINDER.

a chucking grinder, and the name becomes more and more appropriate as we look into the machine and its work.

There are three grinding spindles carried in the head *A* and shown in detail in Fig. 43. Each grinding spindle is independent both as to its drive and horizontal adjustment for its work, this adjustment being controlled by hand wheels *B*, *C* or *D*, and its power by the handle *E*, which controls the position of the driving belt inside the machine.

The work is held in a chuck mounted on the spindle in the work head *F*.

The hand wheel *D* locks the spindles after they have been adjusted, while the wheel *H*, at the extreme left of the machine, controls the in-and-out movement of the work head. The handle for the cross-feed is seen at *I* at the front

of the work slide and below this is the locking lever *J* which clamps the work head, either in line with the spindles or at any desired angle as secured by the graduated disks under the handle *I*. The wheel *K* at the center of the cabinet gives the hand movement of the grinding head and is automatically thrown out as soon as the power feed is thrown in. The lower hand wheel *L* adjusts the power feed from 1/16 to 5/8 in. for each revolution of the work, while two handles *M* and *N* at the right control the speed of the work spindle. The stop lever and reverse stops that control the clutch which gives the grinding head travel either to the right or left are also located as indicated at *O* near the center of the machine.

A SECTIONAL VIEW OF THE MACHINE

Figure 43 gives a better idea of the construction of the machine, showing a section through the work spindle and also through the internal or central

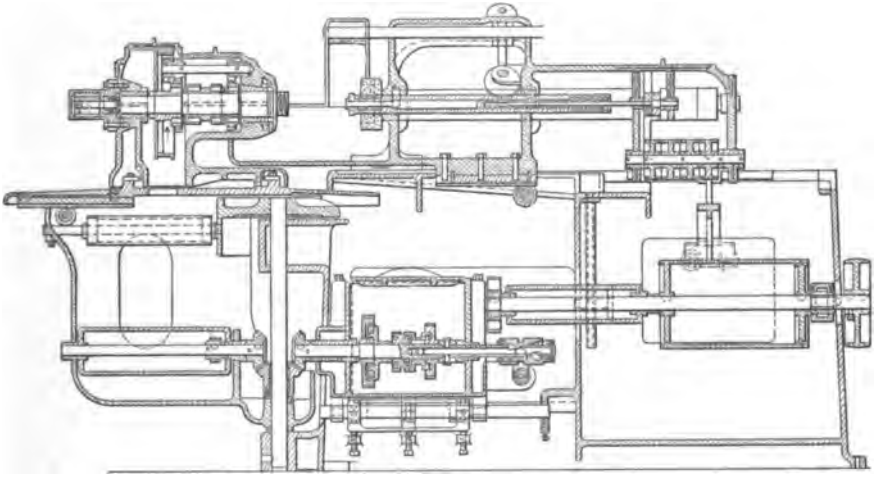


FIG. 43. SECTION THROUGH CHUCKING GRINDING MACHINE.

grinding spindle. Beginning with a single pulley drive at the end, the power is transmitted to the driving mechanism for the feed of the grinding head, and also for revolving the work at the correct speed. The gearing and clutches give nine variations of speed, power being transmitted through three beveled gears around the pivoting and supporting shaft, and by belt from the long drum to the pulley on the work spindle above. The work spindle is also back-geared, as can be readily seen, these being controlled by the handle on the outside of the work head.

On the main shaft coming in from the single drive pulley outside is a long drum and from this the power is transmitted directly to the two outside grinding

spindles above. The center or internal spindle receives its motion indirectly, being driven by a belt from the left-hand pulley on the idler shaft, shown between the main shaft and the grinding spindle. This is arranged so that only one spindle will be in operation at a time, the spindle desired being selected by the position of the belt-shipper handle at the right-hand end (Fig. 42) which shifts the belts inside the machine.

THE GRINDING SPINDLES

The grinding spindles themselves are shown in Fig. 44 in their relative position, from which it will be seen that each spindle is carried in a sleeve and is moved in and out and held in the desired position for the work, together with the sleeve itself. The movement of the whole head keeps the overhang

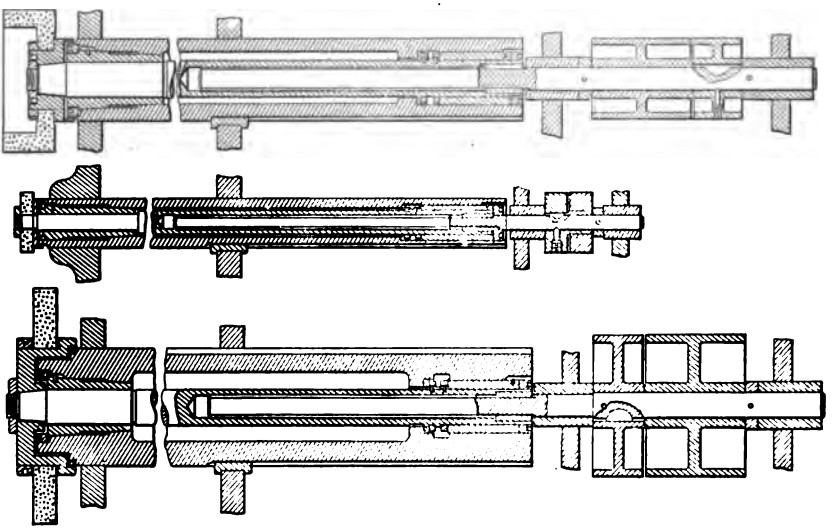


FIG. 44. GRINDING SPINDLES OF BRYANT MACHINE.

the same after it is once set. They are driven by a splined shaft on which the pulley is fixed, the general construction giving an idea of the substantial bearing and the way in which they are supported. All three spindles are clamped by a slight movement of the one handle shown in vertical position near the top of the machine.

The cross-feed mechanism of the work head is controlled by a small handle in front, and three stops are provided, one for each grinding spindle, an ingenious device being used which allows the amount of feed to be gradually reduced automatically so that the last cuts are made with a very light feed, or with it thrown out entirely, assuring accuracy in the finished piece and aiding in duplicating work.

Controlling cams and stops for this device are provided for each spindle and there are also location stops for the entire work head, which determines its movement toward the grinding spindle in operation. These are independent for each spindle and allow the work to be readily set for any desired operation with the assurance that the pieces will all be duplicated.

The cross-sliding head is mounted and gibbed to an intermediate slide having longitudinal traverse.

SOME OF ITS WORK

One of the essential conditions for successful grinding is the right wheel for the work, and this machine allows the proper selection in the same way that a chucking machine has the right tools for every operation.

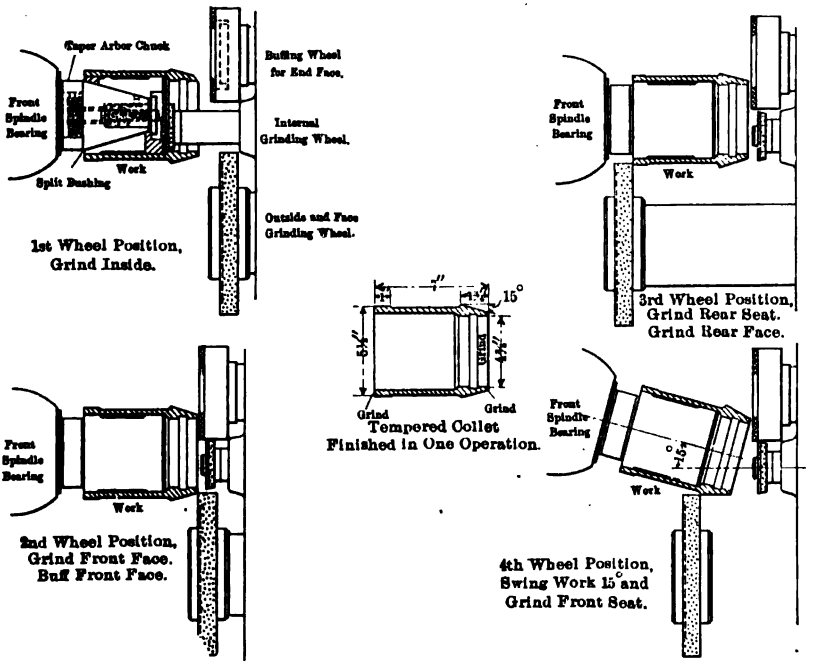


FIG. 45. GRINDING A TEMPERED COLLET.

Taking the work as it comes from the regular chucking machine, either in its natural stage or after heat treatment, this machine offers a way of finishing by grinding with practically the same facility as in the original machining of the piece itself.

Figure 45 shows very clearly the grinding of a tempered collet, which is all done at one operation, although four grinding-wheel positions are necessary. The first of these shows the collar held on a taper draw chuck and the internal-

grinding wheel at work sizing out the nose. In the second position the front face is being ground by the large outside wheel and also being buffed by the wheel on the rear spindle.

In position three, the large wheel is grinding the outside and the back face, while in the fourth position the work spindle has been swung to the necessary angle, 15 degrees, and the outside wheel is grinding the tapered front seat. It will be noticed that the whole work head is swung for angular work around the substantial vertical shaft at the end of the body proper, so that the rigidity of the machine is in nowise affected.

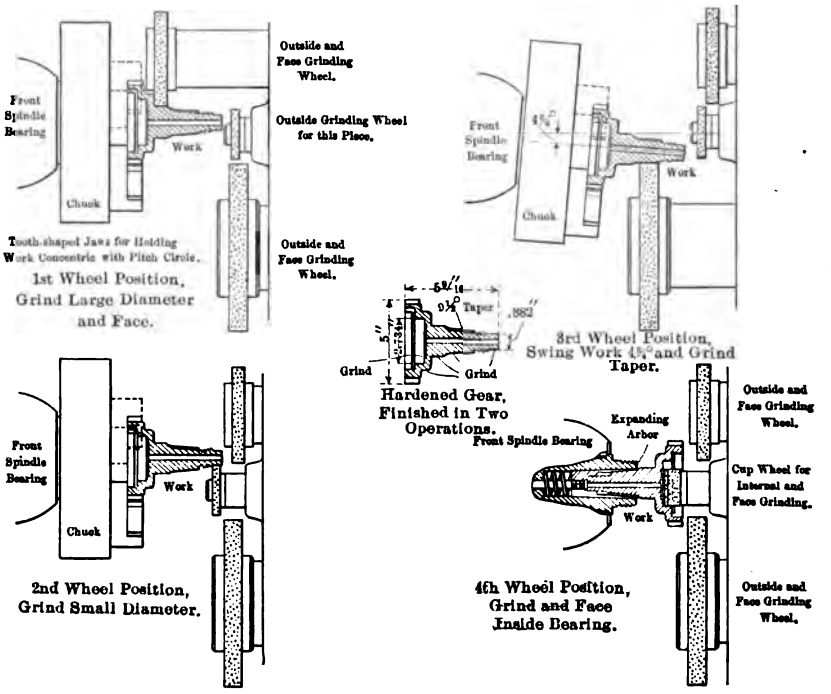


FIG. 46. GRINDING A HARDENED GEAR.

Figure 46 shows a rather complicated grinding proposition in the shape of a special hardened gear with a taper bearing. This is chucked in special tooth-shaped jaws, and the first wheel position shows the back spindle at work. In the second position the small internal wheel is doing external grinding on the small diameter, while in the third position the work has been swung so that the wheel on the front spindle is finishing the taper portion. It is then necessary to reverse the piece and a small cut wheel on the internal spindle is at work inside the gear.

It is not by any means necessary to follow the arrangement of wheels

shown in these illustrations, although for most purposes they will probably be found most convenient, but any desired combination can be used which seems best adapted to the particular work in hand.

An auxiliary fourth spindle is provided for grinding out small holes and can carry wheels small enough to enter a 1/2-in. hole. This may also be used to carry wheels for outside grinding, or for polishing. The machine will grind a piece 12 in. in diameter and 12 in. long. It is regularly supplied with 10-, 6- and 3-in. wheels.

THE NORTON AUTOMATIC GRINDING MACHINE

Figures 47 and 48 show the front and rear views of an automatic grinding machine built by the Norton Grinding Company, Worcester, Mass., for grinding

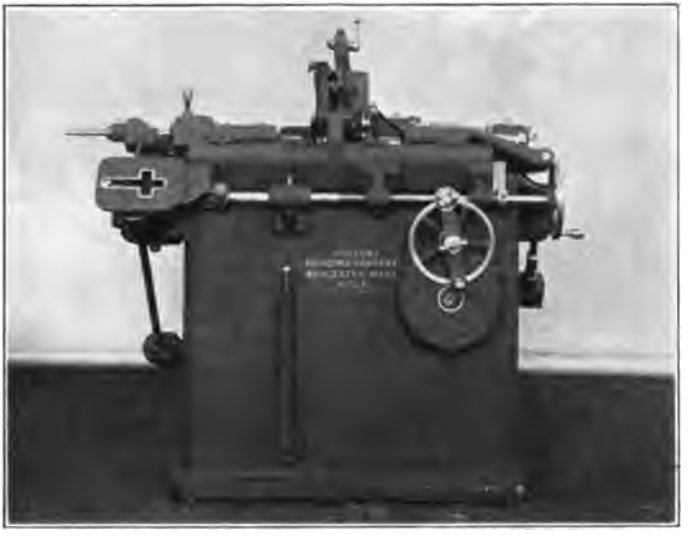


FIG. 47. A 6-IN. AUTOMATIC GRINDING MACHINE.

cylindrical work up to 6 in. in diameter. The machine shown is fitted for grinding the outside of ball races. The rings are held in a magazine feed, ready to roll down and be gripped in the chuck as soon as the retaining plunger is withdrawn at the proper time. The ring, which is dropped out of the chuck, falls on the small chain belt conveyor and is carried in a box placed at the end of the machine.

The heavy grinding head is very similar to that used on the regular Norton machine, but its movement to and from the work is controlled automatically by a cam on the shaft *O*, at the rear, in such a way as to secure absolute certainty of movement at each stroke, as will be seen from the detail engraving in Fig.

49. The grinding wheel is independently driven to secure the correct speed for the wheel, all other movements being timed by gearing from the pulley at the back through the medium of a positive clutch and planetary gearing. This clutch is controlled by the long lever at the front of the machine.

Both the rotation and traverse of the work across the face of the grinding wheel are actuated by shaft *A*, through the bevel gearing shown. The cam which moves the wheel to and from the work is driven by the shaft *O*, through change gears inclosed in case *N*. A shearing pin set in hardened steel plates

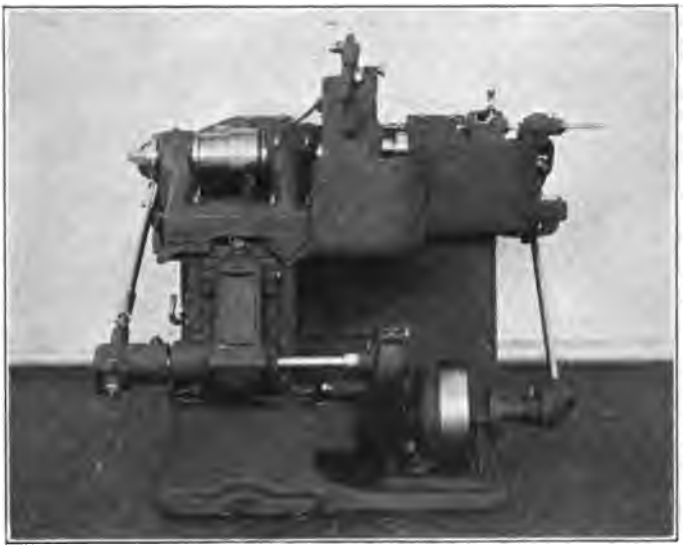


FIG. 48. REAR VIEW OF AUTOMATIC GRINDING MACHINE.

protects the mechanism from injury in case a blank is fed in wrong, or for any other reason. Shaft *E*, which is connected by the universal joints, rotates the disk *G*, which controls the chucking mechanism for holding the work while being ground.

THE CARRIAGE MOVEMENT

The movement of the carriage and the work past the grinding wheel is controlled by shaft *A*, driving the slotted disk *B*, in which the connecting rod *C* is located, to give any desired traverse. Shaft *A* also drives the splined shaft *K* by bevel gearing. This revolves the work-holding spindle through a small gear box *J*. This connecting rod drives the threaded bar shown in front of the machine in Fig. 47, and connects with the work carriage through the nut *D*. This nut allows the carriage to be positioned with reference to

the grinding wheel, and is also used moving the carriage by hand in truing the grinding wheel. By placing a diamond in a suitable place provided in one of the chucking heads, and moving it past the wheel by means of a hand wheel *F*, the wheel is easily trued up.

INSURING CORRECT POSITION OF CARRIAGE

In this connection it is interesting to note the ingenious method of insuring the return of the carriage to its correct position after the wheel has been trued, so that the proper relation between the work to be ground and the face of the grinding wheel, may be preserved.

Two holes are drilled in the face of the crank disk *B*, so that one will come each side of the connecting rod when it is in the position shown. These holes come directly under the short arm of the cross-shaped opening in the cover plate over this disk. A special locating fork is made with a dowel pin in each fork, which fits into the holes in the disk *B*, and as this fork straddles the connecting rod, it locks it in position. Before truing the wheels this fork is inserted through the cross opening, locking the connecting rods, and the diamond is then passed in front of the grinding wheel by moving the whole carriage.

As the guard with the cross-shaped opening is connected to the carriage, it moves with it, the long slot allowing room for the handle of the locating fork. It is, however, impossible to withdraw the fork and release the connecting rod until the carriage has been returned to its original position, when the fork can be readily withdrawn through the cross opening.

CONTROL OF THE WHEEL SLIDE

Figure 49 shows a cross-section through the bed beneath the wheel slide. Connected to the bottom of the wheel slide is the massive nut *A*, having a modified buttress thread and provided with glands on each end, through which the rod *B* passes so as to prevent the oil working out from the reservoir inside the nut. A groove in the bottom of the nut allows the oil free passage from one end to the other. The end of the adjusting screw bears against the end of the rod *C*, this bearing surface being made as true as possible by grinding. Rod *C* is keyed to prevent turning.

The shaft *O* drives the cam *D*, but the cam is supported in its own bearings formed by long hubs on each side of the cam face. The cam turns in the direction shown by the arrow and bears against the lower end of the lever *E*, which in turn forces the rod *C* against the end of *B* and moves the whole wheel slide toward the work. The stop screw *F* is carefully adjusted so as to make contact with the lever *E* at its point of maximum travel. In this way the wheel slide is moved a predetermined distance, and as the lever *E* is brought against a positive stop, while still in contact with the highest point of the cam, the

question of oil film either between D and E or in the bearings of the cam itself is entirely eliminated, as both of these points are in metallic contact at the instant the cam is in the position shown. This makes is possible to secure

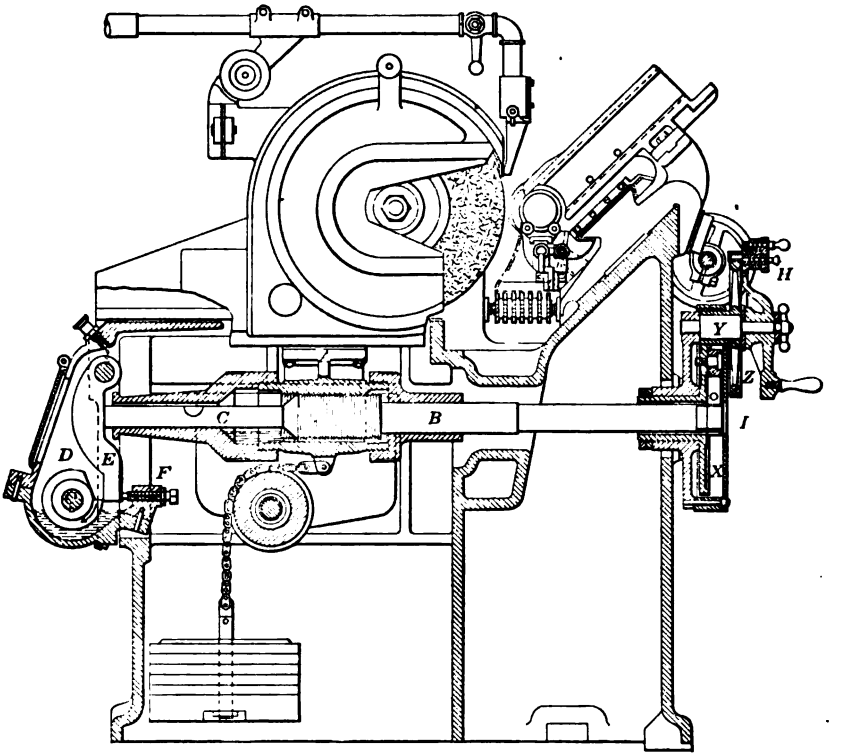


FIG. 49. SECTION THROUGH WHEEL-SLIDE MECHANISM.

duplication of work to within 0.00025 in. in regular practice. The use of a large wheel having a broad face adds to its life, and wheel dressing is not nearly as frequent as might be imagined.

ADJUSTING FOR WEAR OF WHEEL

When it becomes necessary to adjust the wheel slide to make up for wheel wear, the reason for threading the rod B into such a substantial nut becomes apparent. As the wheel wears, it is necessary to screw the rod B into the nut just enough to compensate for the amount trued from the wheel. The end of B is flattened, as can be seen at I, and is carried by a pair of forged-steel clamps. These clamps are fastened to the gear wheel X, which is revolved by the pinion Y through the handle shown. This is for rapid adjustment in setting up for new work. For finer movement the handle H, which controls a small pinion meshing into the large wheel Z, reduces the movement so that moving

H one hole, moves the wheel slide 0.00005 in. This makes it possible to obtain any adjustment that may be needed with ease and certainty.

AUTOMATIC CHUCKING OF THE WORK

Figure 50 shows the chuck-actuating mechanism, driven from the main shaft by the universal jointed rod *E*. The double disks *G* carry a hardened-steel roller between them, as can be seen, and also a releasing pin *W*, on the upper disk, which will be seen to project in Fig. 47. The work is held by being gripped between two plungers, which centers and holds it while being ground.

The movable plunger is controlled by the roller in the plate *G*, acting on the cam lever *T*, which in turn acts on the plunger *U* through the hardened projection on the outer end. The plunger is returned by the spring shown in the sec-

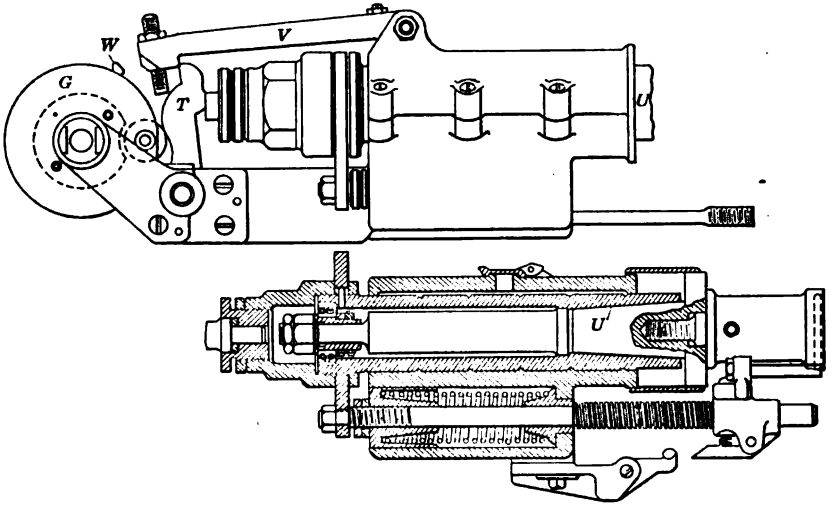


FIG. 50. CHUCK MECHANISM FOR HOLDING WORK.

tional view, and after dropping a piece of work it remains open until the next piece drops into place. Then the roller comes in contact with the cam lever *T*, grips the work and, as soon as *T* reaches its gripping position, the latch *V* drops into place and holds it while the work is being ground. The work remains locked in position until the releasing pin *W* comes under the adjusting screw in the end of the latch *V*, which releases the lever *P* and allows the spring to force back the plunger *U* and release the work. It is then ready to receive the next piece, which rolls into place as soon as the releasing plunger is withdrawn by the opening of the chuck. It will be noticed that the piece which comes in contact with the work is screwed into the end of the plunger and can be readily changed to suit any class of work to be ground. It will also be noted that the work-holding plunger is free to revolve, being driven through the small four-speed gear box *J*, on the other end of the carriage.

CHAPTER III

THE FIELD FOR GRINDING

It is probably true that the majority of engineers do not have a proper conception of the field of metal grinding. Grinding is a manufacturing operation, permitting us to produce certain classes of work cheaper, faster and better than by any other known method. We need, however, a more careful study of the combination of lathe work and grinding to obtain maximum production.

There is no one better qualified by experience to write upon the subject of the grinding machine and its field, than C. H. Norton, of the Norton Grinding Company, whose numerous articles in the *American Machinist*, along with those contributed by other experts in the art of grinding, have proved of the highest educational value to thousands of readers of that journal. In defining the field for grinding,[1] we can do no better than to incorporate in this chapter the greater portion of the paper presented by Mr. Norton before the American Society of Mechanical Engineers at their 1910 fall meeting, and published in slightly condensed form in the *American Machinist* for December 29, 1910. Mr. Norton sets forth the subject of cylindrical grinding as follows:

THE CYLINDRICAL GRINDING FIELD

Grinding in various forms has been known to man from the very beginning of history, yet it is doubtful if many engineers have a clear conception of the field for metal grinding. An experience (as a specialist) covering 25 years has taught that the usual idea of grinding is that it is a slow, tedious, expensive, but sure method of obtaining accuracy, and that where great accuracy is not required grinding should not be done.

Webster defines abrasion as "the act of wearing or rubbing off; the wearing away by friction, as the abrasion of coins." Abrade, "to waste or wear away by friction, as to abrade rocks." He defines the word abraise as "rubbed smooth, as an abraised table," meaning a polished table. No doubt here is the connection between polishing and abrasion.

Some time within the last 75 to 100 years men discovered that a revolving polishing wheel enabled them to abrade work in such a comparatively short time that so far as polishing was concerned it was no longer slow nor tedious. But as the original word for abrasive action was "grind," and grinding was slow, men still clung to the tradition in spite of the later discovery that polishing could

[1] For Surface Grinding see Chapter V.

be done quickly. When, within recollection, mechanics made their own solid glue and emery wheels with which to grind small hardened tool work, it did not occur to them that they could do by grinding a certain part of the work that they were using steel tools for, because it was grinding, and was slow. Moreover, all nice work must of necessity take lots of time, because our older mechanics had said so. It did not occur to them that we could ever have better grinding wheels and better machines in which to use them.

It was at this point in our reasoning that the majority of engineers rested and it is here that we find a large number now. All engineers admit the exactness of grinding, but most of them still believe it to be slow.

"Appleton's Cyclopædia of Applied Mechanics," published as late as 1893, says that emery wheels are employed mainly for producing cutting edges and for smoothing surfaces. Again it says that in all cases of the employment of emery wheels in place of steel cutting tools, the operation is considerably slower, and it may be laid down as a rule that save upon metal too hard to be operated upon with steel tools, the emery wheel cannot compete with the ordinary lathe, planer, milling tool, etc. Observations convince one that a great many American engineers hold the same views.

The intelligent use of the process of grinding yields such large returns that it warrants careful study by the very best engineering and scientific minds and a place in the courses of our technical schools. The field is constantly broadening with each year's improvements in grinding wheels and grinding machines, and it is time that men of brains and education took a hand to help the world to a better knowledge of the science of grinding and grinding wheels.

The results thus far attained warrant a change of the world's idea of grinding and instead of using it as a synonym for slowness, tedious and drudgery, it should be a synonym for rapidity, accuracy and economy.

The fact about grinding with the modern grinding machine and grinding wheel is that it enables us to size all round work cheaper than by turning and filing, that it takes the place of what we formerly called the finish cut of the lathe and all filing, giving us not a theoretically perfect cylinder or perfect finish, but a much nearer perfect cylinder and finish than we obtained with the lathe. It gives us diameters to such small limits as to be called exact, but whoever insists that none but exact work be ground loses the very pith of grinding, which is economy. Modern grinding means cheaper cost for all work, many grades of work to suit many requirements, and cheaper turning than is possible without the use of the grinding machine.

TURNING BEFORE GRINDING

As a rule, the coarser the turning the greater the economy of grinding. The greatest economy is obtained by the combination of cheaper turning and grinding. It is no longer necessary to turn work smooth, straight or correctly

to size and the lathe is no longer necessary as a precision tool. If it has a carriage traverse of from four to ten threads per inch, has sufficient power to carry high-speed tool cuts at that feed and is well supplied with steady rests to prevent springing of the work, it is ready for coöperation with the grinding machine. It is easier with modern grinding machines and wheels to grind off a given amount of metal when in the form of crude screw threads than in any other form, and with long work having several sizes the grinding requires less time if 1/32 in. to 5/64 in. is left on the diameter for grinding than if the work is turned carefully to within 0.002 in. to 0.005 in. In all cases, accurate turning increases the total cost of production and in some it makes the grinding very expensive.

The greatest economy is usually obtained by the combination of grinding with very rough turning. Yet there are cases where the least expensive way is to grind direct without turning, notably the greater part of crank shafts of automobiles and small gas engines and very long and slender work where turning is difficult.

It is not an easy matter to secure such rough turning as true economy requires in connection with grinding. Lack of knowledge of what is needed, coupled with the natural pride the workman takes in doing what tradition says is nice lathe work, prevents the grinding machine from doing what it is ready to do. Our industries are losing much while waiting for the engineer to assume the intelligent guidance of foreman and workmen who, through fear, doubt or prejudice now rob us of the great economies due to modern grinding machines. There is much yet to be learned by foremen and workmen about turning. High-speed steel makes possible much that has not as yet become common knowledge.

The lathe is a very old tool and foremen and workmen have known it for generations, yet few instances have been found where a careful study has been made of the combination of lathe work and grinding to effect the maximum saving. It has been observed that lathe men have not tried to remove metal by increasing the number of cuts and using fast traverse. When urged to take coarse feeds to help the grinding machine to effect a total saving, they have said that they were feeding all that the work would stand. It has been demonstrated that three cuts with a carriage traverse of six per inch has produced certain work in 9 minutes that required 13 minutes to turn in one cut, because the work was so frail that with one cut no faster feed than 32 per inch could be taken. The rough-ridged surface was readily ground by taking 1 minute more than when the turning was finer, the net saving for the job being 3 minutes. In many cases the ridged surface requires no additional time.

In another case where the work was quite firm and was being revolved at a very high speed with a view to getting everything possible from the high-speed tool, the turning required 5 minutes and the grinding 1 minute. A change was made in the feed of the lathe so that without revolving the work any slower

it was turned in 1 minute, leaving a very crude, crooked and bad-looking piece of lathe work. The grinding then required 2 minutes, but the net time saved was 3 minutes. Did it matter how bad a looking lathe job it was if the finished work was perfect and 3 minutes were saved?

There is a rich field for engineers and managers in connection with the lathe and modern grinding. Recent lathe designs provide for high speed of revolution, with sufficient power, quick change to and from back gears, and sufficient rigidity to utilize the limit high-speed steel; but much work is not of sufficient rigidity to permit the maximum use of the tool at fast traverse and deep cuts. In addition, there are thousands of lathes of old design that will not be thrown away at once. There is, therefore, an opportunity to get much more out of present plants by cheaper turning, *because of grinding.*

Developments warrant the conclusion that we should no longer assume that simply because a tool is a grinding wheel it cannot remove metal and size and shape work as quickly as a steel tool. Rather, we should use the steel tool when it can be made to remove metal, size and shape work cheapest, and the grinding wheel when it excels. It is no longer to be taken as a matter of course that we can turn, plane and mill faster than we can grind. After all, the real reason we remove metal is to accomplish certain finished results, not simply to secure a certain number of pounds of chips in a given time. Before long probably all progressive engineers will understand that both the grinding wheel and the steel tool have their place for metal cutting. The old thought of abrasion must give way to the new thought of cutting.

While it is still true that poor wheels or good wheels poorly selected and wrongly used will still remove metal very slowly by abrasion, it is also true that the old-fashioned milling cutter, with fine teeth cut by hand with a file, hardened but never ground, and used in the old-time slender milling machine would very slowly abrade the surface. The modern grinding wheel, used in a modern machine by a modern man, is just as surely a milling cutter as if it were made of steel.

The microscope reveals the fact that such a wheel cuts off chips.[1]

The grinding wheel as now made is really a milling cutter with millions of cutting teeth. Although these teeth are not as large or as strong as the teeth of a steel cutter and, therefore, cannot cut as deeply, yet they are capable of cutting at much greater speed. Since there are so many more of them they are capable of much more work in a given time when the nature of the work is such that a large number of these cutting points can be used simultaneously. In some cases we can use as many as 2 billion cutting points per minute. Eight hundred million per minute is not uncommon and 400 million per minute is very common.

The modern grinding wheel, mounted in a good machine, can be used at a cutting speed of 6000 or more surface feet per minute and owing to this high

[1] See Chapter IX, The Chips of the Grinder.

speed it need not cut deeply relative to the rigidity of the work. Therefore it is able to remove metal from many forms of work more quickly than the milling cutter or the lathe tool.

AN ILLUSTRATION—GRINDING AUTOMOBILE CAMS

The accompanying illustrations show a notable example. In Fig. 51, Nos. 1 to 4, inclusive, show the process of making automobile cams. An order for a hundred of these cams was received and the shop superintendent began to provide means for producing them at the lowest possible cost. It is evident that drop forgings for so few would be out of the question, as the expense of dies would make the cost of the cams prohibitive. It was, therefore, necessary

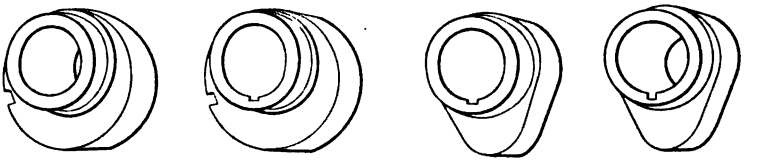


FIG. 51. GRINDING CAMS FOR AUTOMOBILE ENGINES.

to devise means for producing them from the bar stock. This was done by providing an eccentric chuck for the automatic screw machine. To prevent the bar from turning in the chuck while feeding forward, the spline was made the full length and a mating key was placed in the chuck. Pieces like No. 1 were made in the automatic machine at the rate of 10 per hour. A keyway in the hole was made in the ordinary way, No. 2. These blanks were ground to rough shape, No. 3, at the rate of 10 per hour. The cams were then hardened and finished ground to No. 4 at the rate of 40 per hour. It should be clear that such a cam could not be milled to shape from the blank in nearly so short a time with the milling cutter. When manufacturing such cams in large numbers drop forgings would be used, and here again the grinding wheel is quicker than the milling cutter.

GRINDING PINS AND BEARINGS OF AUTOMOBILE CRANKSHAFTS

Another case where the grinding machine can accomplish the results desired in less time than the lathe is that of the pins and bearings of the automobile crankshaft. The results desired are as follows: Five bearings, all round within 0.00025 in.; the axis of all parallel and exactly in line; all of the right length within 0.004 in.; distance between bearings within 0.004 in.; accumulated error not over 0.008 in. Four crank pins, all round within 0.00025 in.; the axis of all exactly parallel; all to length within 0.004 in.; all parallel with the bearings; all within 0.005 in. of the same plane; all of correct throw, within 0.010 in.;

overall length, accumulated error not over 0.008 in.; all fillets correct radius and exactly concentric with the bearings and pins; all bearings and pins straight within 0.00025 in.; and all a good, smooth surface.

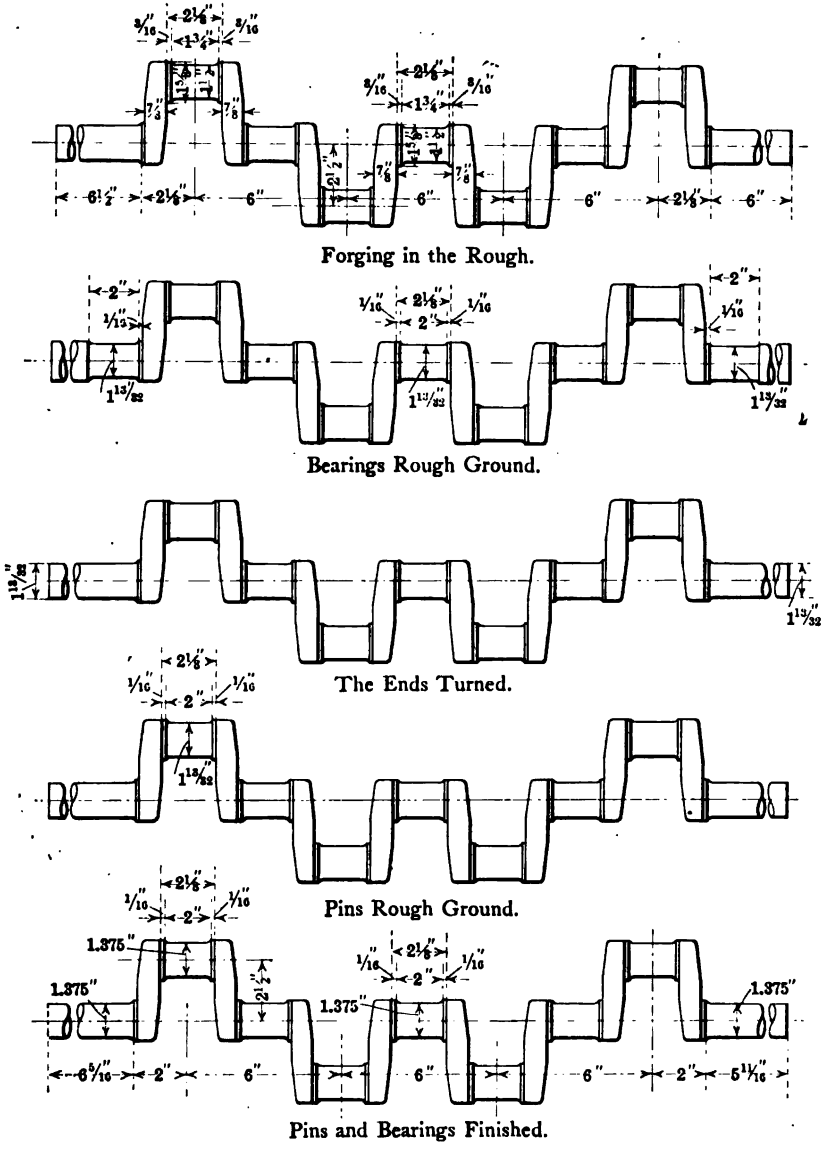


FIG. 52. STAGES IN THE GRINDING OF AN AUTOMOBILE CRANKSHAFT.

In the case of cranks designed with clearance for the arms of the cranks, as shown in Fig. 52, the width of the wheel is identical with the required length of

the pins and bearings, so that no measuring or setting of the tool is necessary for cutting to length. The act of grinding cuts the bearing or pin the right length and forms the fillets. The location of the pins and bearings within the small limits allowed is accompanied by a massive index bar, so that the workman does no measuring whatever for location of bearings or pins. The entire time of handling and producing these five bearings and four pins from the rough forging to the nicely sized and finished condition is 85 minutes. It is clear that when all the conditions of the finished work are considered the grinding wheel and machine have removed metal faster than the lathe. Again, it is not simply a case of removing pounds of metal per hour, but the removal of it in such a manner as to accomplish certain results in the least time.

The ends of these shafts beyond the bearings are turned before grinding The entire list of operations to make a finished shaft from the forging is as follows:

	Minutes
Cut off ends and center	6
Rough grind bearings	15
Turn ends	8
Rough grind pins	20
Finish grind pins	20
Finish grind bearings and ends	25
Square ends	6
Total time	100

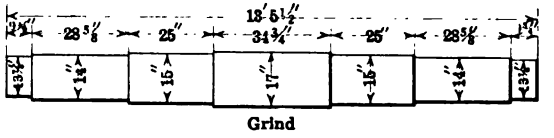
A little time could be saved if it were practical to secure forgings with pins and bearings 1 5/8 in. in diameter over their entire length instead of with the depression to 1 1/2 in. between shoulders, as the wheel can be forced more rapidly when the face has the same amount of work to do as the fillets. Here again tradition is strong and difficult to change at once, because the depression is better for those who turn the work. A little coöperation would save on dies and time in grinding.

OTHER ILLUSTRATIONS

There are many other cases where the grinding wheel is used to remove metal in a more economical manner than with steel-cutting tools, some of which are shown in Figs. 53 and 54.

Automatic grinding is a late development in the field. Certain work of which large numbers of pieces are made is ground by wholly automatic means. The work is conveyed to the machine by gravity in a hopper or chute and is chucked, ground and delivered to the receptacle. In a case where formerly, at piece work, 300 per day were ground, the automatic machine grinds four in a single minute, about 2300 per day.

When the knowledge of grinding becomes more common, the field will be still more extended. It is worthy of more systematic coöperation and if we



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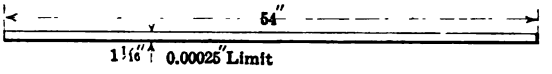

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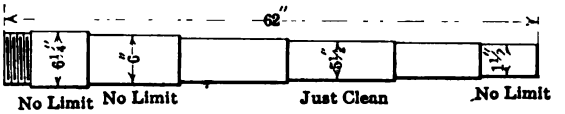

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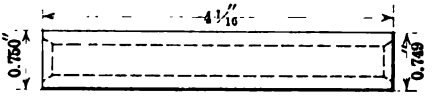

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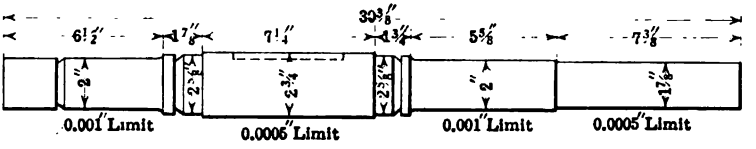

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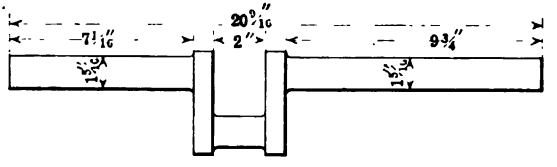
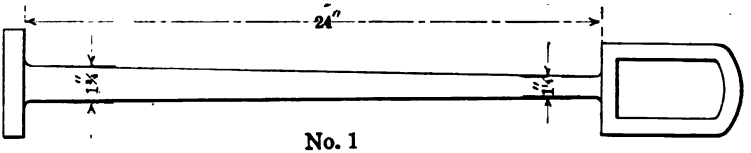


No. 6

FIG. 53. WORK DONE ON CYLINDRICAL GRINDER.

get together we will be rewarded with success. The engineer is the one who by education and training is best fitted to take up the important question of the field for grinding.



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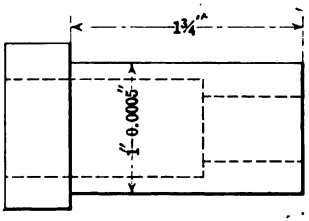

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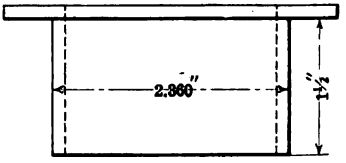

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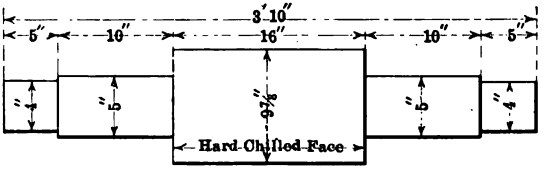

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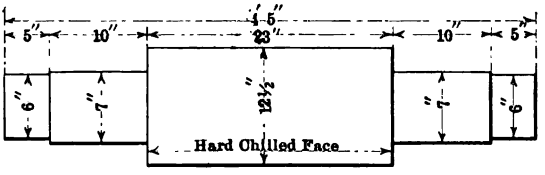

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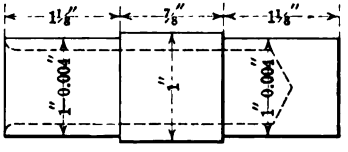


No. 6

FIG. 54. WORK DONE ON CYLINDRICAL GRINDER.

CHAPTER IV

CYLINDRICAL GRINDING

This chapter in a certain sense may be considered a continuation of the one preceding, which is also devoted largely to details of operations on the cylindrical grinder, giving times required for certain pieces, stock allowances for removal with the wheel, and other particulars related to the subject. The relation between turning and grinding was there described by C. H. Norton, who states that as a rule the coarser the turning the greater the economy in grinding.

Some further data on the combination of turning and grinding operations are included in the present chapter and this information is followed by particulars from different experts on methods of handling various kinds of grinder work under all sorts of conditions.

It may be well to repeat here from a letter of Mr. Norton's a few statements relating to grinding times:

"The grinding machine in itself, without the aid of the lathe man, is not an economy and our grinding machine, being made especially with a view to saving lathe work, is more expensive than the old line of grinding machines have been when the aim was simply to grind the surface after it had been accurately turned. We cannot separate the grinding from the turning and show economy. We therefore feel diffident about publishing grinding times without each time publishing with it a very long article telling how to turn work. Where we have been able to get our friends to turn their work in an economical way suitable for grinding with our machines we have been able to show great economy."

THE WORK AND THE TIME

In the examples shown with this the turning time is given whenever possible as it is on the total turning and grinding time that the real economy depends. In fact the economy of the process comes from a saving in the turning and unless this is made, finishing by grinding may become an expense instead of an economy. True it gives an accuracy in roundness that is ahead of any turning process, but it is not economy to have this an additional expense when it can be had at the same or at a lower cost than turning in the old way.

So the first step in using a grinder economically is to learn how to turn work that is to be finished in that way. We must forget the old way of turning pieces with a smoothing cut to a diameter very close to size, and then finishing by grinding with a light grinder that would not stand any kind of a cut without springing. This was when finishing by grinding was an expense

that was endured because of the greater accuracy. But this is no longer necessary and cannot be afforded if we are to compete with others who are taking advantage of the newer methods and heavy grinding machines that are now on the market.

If the time given in the following examples seems short, don't assume that it is impracticable until you try the work with the proper preliminary turning and remember that the turning time must be much less than if the piece is finished entirely in the lathe, or there is no advantage in the grinding method except the greater accuracy obtained.

The first example in Fig. 55 is plain grinding from cold-rolled steel stock where only 0.018 in. was removed so that no turning was necessary. The wheel used was a 24-in. combination grit of L grade and 15 pieces were ground in 44 minutes.

The next example, No. 2, was turned to closer limits than is desirable for economy and as the turning time is not known we cannot compare the total cost of finishing with the other pieces. The limits of accuracy are very close on some parts as can be seen from the sketch. The material is 0.30 carbon steel, stock removed 0.018 in., the wheel 24.-in. combination L, as before and 12 pieces were ground in 150 minutes, or 12 1/2 minutes each, but a single piece is not as good a test as the average of a lot.

A similar piece is shown in No. 3, which is also a low-carbon steel. The stock removed was only 0.015 in. in this case. The same wheel is used. The limit on bearings was 0.0005 in. only; 25 pieces were ground in 505 minutes or 20 1/5 minutes each as an average.

The rest of the examples show the turning time, which it will be seen is very low indeed and shows where a decided economy can be effected over usual practice.

Number 4 was rough turned in one cut (the sketch not being to scale is a little confusing in this, but the diameters given show that this is easily possible) leaving 3/64 in. for grinding. The turning speed was 60 ft. per minute with a feed of 1/16 in. per revolution and the turning time was only 20 minutes. Then the ends were squared up, oil grooves cut and shoulders finished, which took 50 minutes more. The grinding averaged from 30 to 40 minutes, but a single piece of this kind has been done in 18 minutes. The total time per piece was 100 to 110 minutes.

Number 5 is another example of the same kind which was rough turned in one cut so as to leave 3/64 in. of stock for finishing, being turned at 65 ft. per minute with a feed of 1/8 in. per revolution. Turning time was 15 minutes. The squaring up of the ends, finishing of shoulders and cutting of thread took 45 minutes. The grinding averaged to take 30 to 40 minutes, although a single piece has been done in 14 minutes. The total time was 90 to 100 minutes.

The last example is somewhat similar to No. 4, but is shorter so that it takes less time to go over it. This was rough turned in two cuts, leaving 1/32 to

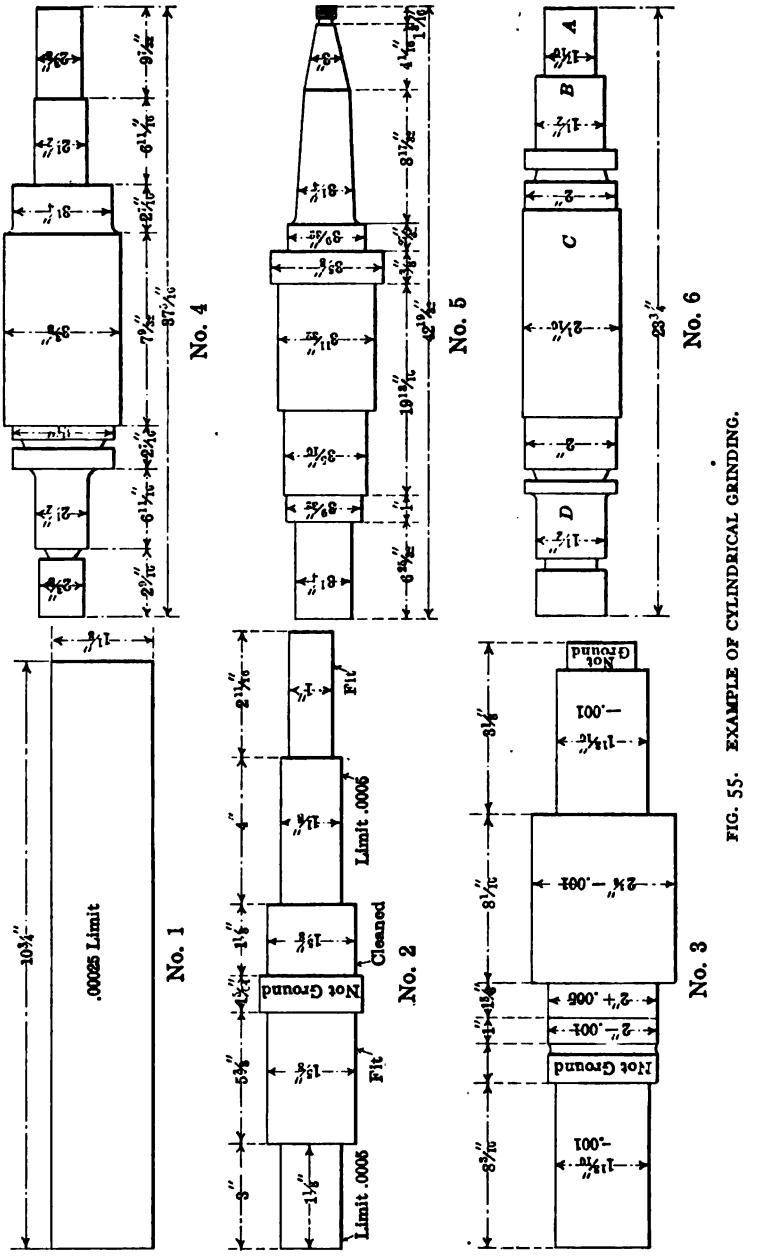


FIG. 55. EXAMPLE OF CYLINDRICAL GRINDING.

grind. Turning time 20 minutes. Ends were squared, shoulders finished and oil grooves cut in 25 minutes. Grinding time 18 to 22 minutes. Here the parts *A* and *C* were ground to limits of 0.0005 in. and *B* and *D* to 0.001 in., while all lengths are to gage. The total time on the piece is from 60 to 70 minutes.

In all grinding it is necessary to use the wheel best suited to the work to get the best results and in this there seems no better way than to tell the wheel-maker just what the work is.

The examples shown with this were furnished by the Norton Grinding Company, Worcester, Mass.

LIMITS IN GRINDING—GRINDING ALLOWANCES AND TIMES

As is the case with all other branches of machine work, grinder practice varies in different shops and the recommendations of grinder builders themselves show interesting variations in regard to speeds, feeds, allowances in turning for finishing with the wheel, wheel selection, etc.

Different firms have compiled much valuable material in the way of grinding limits and allowances and some very useful data of this character from the records of the Brown and Sharpe Manufacturing Company, Providence, R. I., are presented herewith along with illustrations of work of various kinds, and particulars of the time required for grinding under the conditions specified.

These data were originally presented in a paper read by W. A. Viall before the American Society of Mechanical Engineers in 1910. Mr. Viall's paper in substance is as follows:

In considering a piece of work to be ground, first of all the question arises as to the size and the limits suitable for the purpose for which it is intended. Table 1 gives the limits used at the Brown & Sharpe Manufacturing Company's works for varying conditions. There are special cases where it may be necessary to increase or to decrease these limits, and this table is not offered as the final word but as a guide toward selection.

RUNNING FITS—ORDINARY SPEED

To ½-in. diameter, inc.	0.00025 to 0.00075	Small
To 1 -in. diameter, inc.	0.00075 to 0.0015	Small
To 2 -in. diameter, inc.	0.0015 to 0.0025	Small
To 3½-in. diameter, inc.	0.0025 to 0.0035	Small
To 6 -in. diameter, inc.	0.0035 to 0.005	Small

RUNNING FITS—HIGH SPEED, HEAVY PRESSURE AND ROCKER SHAFTS

To ½-in. diameter, inc.	0.0005 to 0.001	Small
To 1- in. diameter, inc.	0.001 to 0.002	Small
To 2 -in. diameter, inc.	0.002 to 0.003	Small
To 3½-in. diameter, inc.	0.003 to 0.0045	Small
To 6 -in. diameter, inc.	0.0045 to 0.0065	Small

SLIDING FITS

To ½-in. diameter, inc.	0.00025 to 0.0005	Small
To 1 -in. diameter, inc.	0.0005 to 0.001	Small
To 2 -in. diameter, inc.	0.001 to 0.002	Small
To 3½-in. diameter, inc.	0.002 to 0.0035	Small
To 6 -in. diameter, inc.	0.003 to 0.005	Small

STANDARD FITS

To ½-in. diameter, inc.	Standard to 0.00025	Small
To 1 -in. diameter, inc.	Standard to 0.0005	Small
To 2 -in. diameter, inc.	Standard to 0.001	Small
To 3½-in. diameter, inc.	Standard to 0.0015	Small
To 6 -in. diameter, inc.	Standard to 0.002	Small

DRIVING FITS—FOR SUCH PIECES AS ARE REQUIRED TO BE READILY TAKEN APART

To ½-in. diameter, inc.	Standard to 0.00025	Large
To 1 -in. diameter, inc.	0.00025 to 0.0005	Large
To 2 -in. diameter, inc.	0.0005 to 0.00075	Large
To 3½-in. diameter, inc.	0.00075 to 0.001	Large
To 6 -in. diameter, inc.	0.001 to 0.0015	Large
To ½-in. diameter, inc.	0.0005 to 0.001	Large

DRIVING FITS

To 1 -in. diameter, inc.	0.001 to 0.002	Large
To 2 -in. diameter, inc.	0.002 to 0.003	Large
To 3½-in. diameter, inc.	0.003 to 0.004	Large
To 6 -in. diameter, inc.	0.004 to 0.005	Large
To ½-in. diameter, inc.	0.00075 to 0.0015	Large

FORCING FITS

To 1 -in. diameter, inc.	0.0015 to 0.0025	Large
To 2 -in. diameter, inc.	0.0025 to 0.004	Large
To 3½-in. diameter, inc.	0.004 to 0.006	Large
To 6 -in. diameter, inc.	0.006 to 0.009	Large
To ½-in. diameter, inc.	0.00025 to 0.0005	Large

SHRINKING FITS—FOR PIECES TO TAKE HARDENED SHELLS ⅛ IN. THICK AND LESS

To 1 -in. diameter, inc.	0.0005 to 0.001	Large
To 2 -in. diameter, inc.	0.001 to 0.0015	Large
To 3½-in. diameter, inc.	0.0015 to 0.002	Large
To 6 -in. diameter, inc.	0.002 to 0.003	Large
To ½-in. diameter, inc.	0.0005 to 0.001	Large

SHRINKING FITS—FOR PIECES TO TAKE SHELLS, ETC., HAVING A THICKNESS OF MORE THAN ⅛ IN.

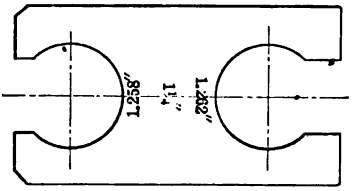
To 1 -in. diameter, inc.	0.001 to 0.0025	Large
To 2 -in. diameter, inc.	0.0025 to 0.0035	Large
To 3½-in. diameter, inc.	0.0035 to 0.005	Large
To 6 -in. diameter, inc.	0.005 to 0.007	Large
To ½-in. diameter, inc.	Standard to 0.0005	Large

GRINDING LIMITS FOR HOLES

To 1 -in. diameter, inc	Standard to 0.00075	Large
To 2 -in. diameter, inc	Standard to 0.001	Large
To 3½-in. diameter, inc	Standard to 0.0015	Large
To 6 -in. diameter, inc	Standard to 0.002	Large
To 12-in. diameter, inc	Standard to 0.0025	Large

The limits given in the table can be recommended for use in the manufacture of machine parts to produce satisfactory commercial work. These limits should be followed under ordinary conditions. Special cases should always be considered, as it may be desirable to vary slightly from the tables.

TABLE I.—GRINDING LIMITS FOR CYLINDRICAL PIECES
AS ADOPTED BY BROWN AND SHARPE MFG. CO.



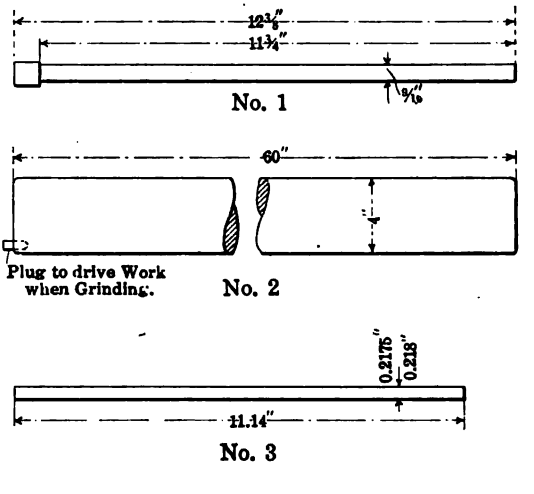
Size	Not go on	Go on	Size	Not go on	Go on	Size	Not go on	Go on
	Inches			Inches			Inches	
3/8	0.383	0.387	15/16	0.9455	0.9495	1 1/2	1.508	1.512
7/16	0.4455	0.4495	1	1.008	1.012	1 5/16	1.5705	1.5745
1/2	0.508	0.512	1 1/16	1.0705	1.0745	1 5/8	1.633	1.637
9/16	0.5705	0.5745	1 1/8	1.133	1.137	1 11/16	1.6955	1.6995
5/8	0.633	0.637	1 3/16	1.1955	1.1995	1 3/4	1.758	1.762
11/16	0.6955	0.6995	1 1/4	1.258	1.262	1 13/16	1.8205	1.8245
3/4	0.758	0.762	1 5/16	1.3205	1.3245	1 7/8	1.883	1.887
13/16	0.8205	0.8245	1 3/8	1.383	1.387	1 15/16	1.9455	1.9495
7/8	0.883	0.887	1 7/16	1.4455	1.4495	2	2.008	2.012

TABLE 2.—LIMIT GAGES FOR LATHE WORK WHICH IS TO BE FINISHED BY GRINDING

The second necessity is that sizes should be established to which the work should be rough turned ready for the grinding room. In the above works, as in all factories, the aim is to produce the desired results as cheaply as possible. The desired ends have been accuracy and nicety of finish where the parts ground are for fits, and nicety of finish where no fit is required. To do this work as cheaply as possible this company believes that it is economical to turn the pieces to about the sizes indicated in Table 2. It will be noted that from 0.008 in. to 0.012 in. in diameter, is allowed, an amount easily obtained by the ordinary class of lathe help. In order to make this work as easy as possible for the lathe

Example No.	1	2	3	4	5	6
Material	Soft machinery steel.	Machinery steel.	Machinery steel, case-hardened.	Machinery steel, case-hardened.	Cast iron.	Bearing bronze.
Part ground	External.	External.	External.	Internal.	External.	External.
Machine used	No. 11 plain.	No. 28 plain.	No. 11 plain.	No. 1 universal (special).	No. 11 plain.	No. 14 plain.
Wheel used	Monarch, 12 in. × 1 in. corundum, No. 46, grade 2½.	Norton, 24 in. × 2 in. alundum, No. 3846, grade K.	Norton, 12 in. × ½ in. alundum, No. 36, grade 5, elastic.	Norton, 2½ in. × 2 in.; alundum, No. 5, grade 2½ elastic.	American, 12 in. × 1 in. corundum, No. 46, grade K.	Abrasive, 16 in. × 1½ in., corundum, No. 60 grade L.
Periphery speed of work, feet per minute.	35	35 roughing; 60 finishing.	35	100	55	75
Travel of work, in. per minute.	96	48 roughing; 30 finishing.	13	By hand.	37	30
Periphery speed of wheel, feet per minute.	7000	6000	5500 to 6000	5500	6500	6000
Amount of stock removed, diameter.	0.012 in. roughing, 0.005 in. finishing.	0.025 in. roughing. 0.005 in. finishing.	0.005 in. roughing. 0.001 in. finishing.	0.018 in. to 0.020 in. 0.010 in. to 0.010 in.	0.020 in. to 0.025 in.	0.012 in. to 0.015 in.
Number of pieces completed per hour.	13	3.5	15	16 20	54	32 59 1 man. 2 men.[1]
Required limit	Standard to 0.00025 in. small.	Standard to 0.001 in. small.	Standard to 0.0005 in. small.	Standard to 0.0005 in. large.	Standard to 0.0005 in. small.	Standard to 0.0005 in. small.
In lots of	100	50	500	200	200	100
Remarks	21 roughed; 35 finished per hour. Handled twice.	7 roughed; 7 finished per hour. Handled twice.	Handled twice roughing and twice for finishing.			[1] A man operates the machine and a helper puts the work on and off the arbor.

TABLE 3.—GRINDING RECORDS—SEE NUMBERS 1 TO 6 INCLUSIVE, FIG. 56



56.

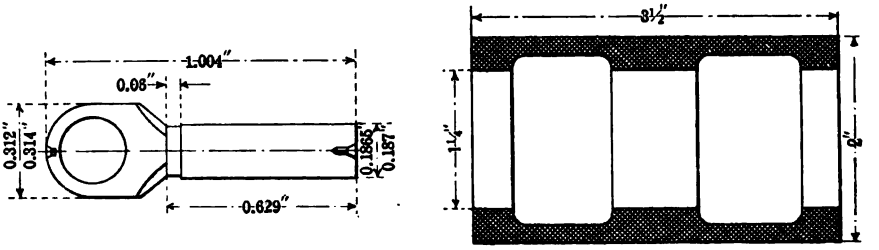


FIG. 57. SEWING MACHINE PLUNGER—CASE HARDENED. BRONZE BUSHING.

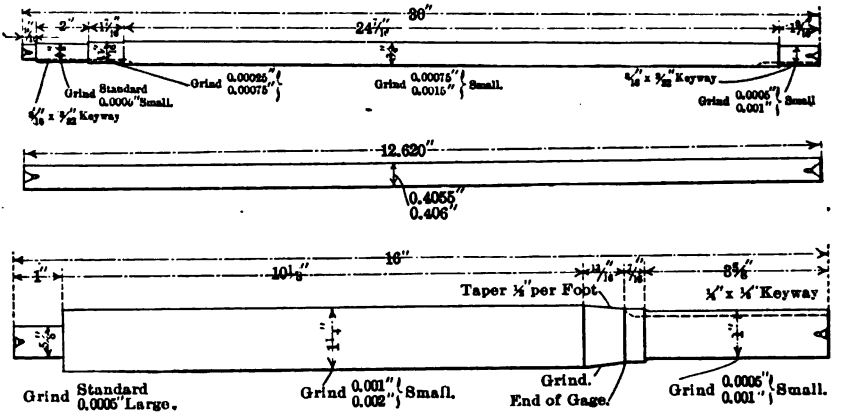


FIG. 58. EXAMPLES OF CYLINDRICAL GRINDING.

department, the limit gage shown in the sketch, Fig. 55 is furnished. Practice varies on this point, and a thorough endeavor has been made to try out the plan of allowing correct limits, but it has been found fully practicable to hold the lathe to the limits given. By so doing the finished product is obtained free from all tool marks and at what is believed to be the minimum cost.

EXAMPLES OF COMMERICAL GRINDING

In Fig. 56, Nos. 1 to 6 show some samples of commerical grinding taken from actual practice for the purpose of giving an idea of what can be done in a commercial way, as well as to give some definite data as to speeds, feeds, etc. While it is perhaps not possible to give a rule that will fit all work, these illustrations should suggest ideas that will help in producing the work as well and as cheaply as this has been done in the cases shown. When enough pieces of any kind are to be made it is possible to specialize to a higher degree than can be done in the general run of work, and better results may be obtained than are shown here.

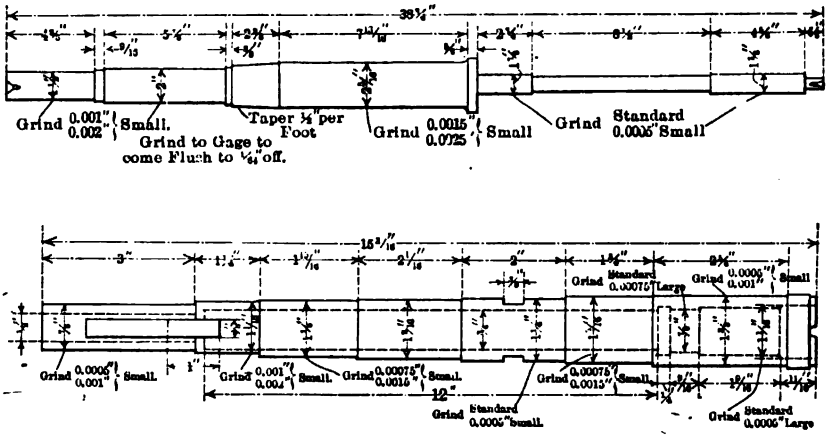


FIG. 59. EXAMPLES OF CYLINDRICAL GRINDING.

The examples of commercial grinding given in Nos. 1 to 6 illustrate what is being done under actual working conditions in commercial work on the variety of pieces indicated, which are of various materials, both soft and hard. A reversal of the usual rule, where economy is gained by having one man operate more than one machine, is shown in No. 6, where work is most economically produced by using two men to run one machine, that is, having one man to operate it and a helper to drive the work on and off the arbor. All other data are based on one man to a machine.

These pieces passed inspection within the limits given. The average loss from work of this class coming below the required limit or being otherwise spoiled is less than 1/4 of 1 per cent. in the grinding department.

The examples shown in Figs. 57, 58 and 59 are each notated to show the peculiar features that exist in the work, together with the data that may be of help in deciding upon other work of this class.

ANOTHER TABLE OF GRINDING ALLOWANCES

One of the features of Mr. Viall's paper on the preceding pages is the table of limit gage sizes to which work is turned before going to the grinders. Table 4, below, shows the practice of the Landis Tool Company, Waynesboro, Penn., in reference to grinding allowances. This table covers work up to 12 in. diameter, and lengths to 48 in.

Length	3″	6″	9″	12″	15″	18″	24″	30″	36″	42″	48″
Diam.											
½	.010	.010	.010	.010	.015	.015	.015	.020	.020	.020	.020
¾	.010	.010	.010	.010	.015	.015	.015	.020	.020	.020	.020
1	.010	.010	.010	.015	.015	.015	.015	.020	.020	.020	.020
1¼	.010	.010	.015	.015	.015	.015	.015	.020	.020	.020	.020
1½	.010	.015	.015	.015	.015	.015	.020	.020	.020	.020	.020
2	.015	.015	.015	.015	.015	.020	.020	.020	.020	.020	.025
2¼	.015	.015	.015	.015	.020	.020	.020	.020	.020	.025	.025
2½	.015	.015	.015	.020	.020	.020	.020	.020	.025	.025	.025
3	.015	.015	.020	.020	.020	.020	.020	.025	.025	.025	.025
3½	.015	.020	.020	.020	.020	.020	.025	.025	.025	.025	.025
4	.020	.020	.020	.020	.020	.025	.025	.025	.025	.025	.030
4½	.020	.020	.020	.020	.025	.025	.025	.025	.025	.030	.030
5	.020	.020	.020	.025	.025	.025	.025	.025	.030	.030	.030
6	.020	.020	.025	.025	.025	.025	.025	.030	.030	.030	.030
7	.020	.025	.025	.025	.025	.025	.030	.030	.030	.030	.030
8	.025	.025	.025	.025	.025	.030	.030	.030	.030	.030	.030
9	.025	.025	.025	.025	.030	.030	.030	.030	.030	.030	.030
10	.025	.025	.025	.030	.030	.030	.030	.030	.030	.030	.030
11	.025	.025	.030	.030	.030	.030	.030	.030	.030	.030	.030
12	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030

TABLE 4.—ALLOWANCES FOR GRINDING (LANDIS TOOL CO.)

FURTHER EXAMPLES IN MODERN GRINDING PRACTICE

A number of interesting examples of work of all kinds performed upon the grinder are described in the following pages, these examples in most cases having been ground by H. Darbyshire, and illustrated by him in the *American Machinist.*

GRINDING SPHERICAL-END ROLLERS

Some roller bearings were wanted in large quantities of a size and shape shown in Fig. 60. They were made from 5/8-in. bar stock in a Herbert turret lathe, one spherical end being formed by an end-rounding tool in the turret and the other by means of a form-cut-off tool held in the tool post. A chip was taken over the body leaving from 0.010 to 0.015 in. for removal by grinding, one end only being centered; they were then carbonized and allowed to cool slowly in a box of lime to give them something of an annealing process. After this they were reheated and plunged vertically in an acid bath to harden them. A No. 3 Brown & Sharpe universal machine with a few little innovations, was used to

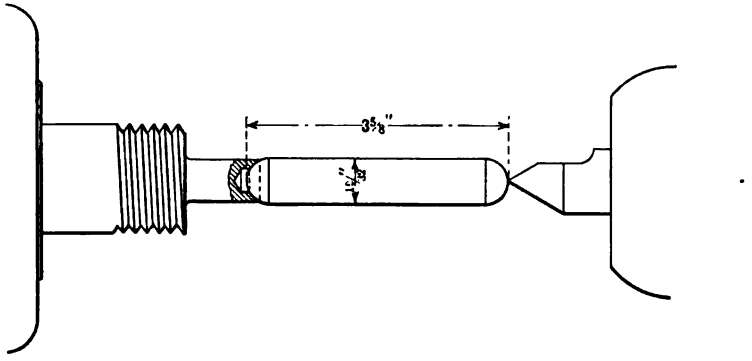


FIG. 60. GRINDING A SPHERICAL-END BEARING ROLLER.

grind them. It being considered that a faster table feed than was provided would be of some advantage a wood sheath was fitted to the cone pulley of the overhead work which increased the table feed about 80 per cent. The work was driven by means of a plug fitted in the center hole of the fast headstock, as shown in Fig. 60, the pressure of the center in the spring poppet being sufficient to prevent any slipping; with this method of driving it was not necessary to stop the work driver to place in position or remove the work. That is, the universal head ran continuously and the work could easily be removed or placed in the machine while the spindle was running. The rollers were first roughed down with the automatic feed to within 0.0015 to 0.0025 in. of finished size at the rate of 138 per hour. A Norton 46K wheel was used with 1-in. face and a cross-feed

of six teeth, or 0.0015 in. was given at each end of the stroke. For finishing the same wheel was used, nicely trued up, one tooth feed being used, of 0.00025 in. at each end of the stroke and 125 per hour were finished to a limit of 0.000125 plus and minus. The same speeds of work, wheel and table were used throughout, the work revolving at 180 r. p. m., the wheel speed being 5500 ft. per minute. The wheel lost in roughing out an average of 0.001 in. in diameter in roughing nine pieces, but in finishing it maintained its size for an average of 30 pieces. The gaging was done with an ordinary tolerance snap gage and after a few dozen had been ground it was found that applying the gage was merely a matter of form, that is to say, it was possible to guess pretty correctly when the work was to size by the density of the sparking from the wheel and the gage was only applied to about every twentieth piece ground. That this judgment was effective may be gathered from the fact that only an average of 3 per 1000 had to be returned to the machine for a slight reduction.

HANDLING LARGER STOCK

These roller bearings were made from 5/8-in. cast steel of a medium quality, and there being only 1/32 in. for removal, by turning and grinding, the bars had to be reeled very true. After a batch of some 4000 had gone through the stock of bar steel ran out and until it could be renewed it was resolved to use steel of the next size in stock, this being 11/16 in. in diameter. There now being ample material to remove it was not thought necessary to reel the stock and some hundreds were made from the raw bar. While all the rollers made from the smaller stock had gone through without trouble, about 20 per cent. of those made from the larger stock were distorted after hardening and would not clean up to size; an attempt to straighten some of these resulted in breakages in many cases, in other cases where the straightening had been successfully accomplished and the pieces had cleaned up to size, they were rejected at the inspection bench as being bent and this was some proof that the straightening process had been a waste of time. It was assumed that the larger steel being of exactly the same quality, the whole trouble was due to not first reeling the stock, and that during the annealing or hardening process it had changed its shape; however, the 5/8-in. bars weighed less and came cheaper and a fresh supply coming in the rollers were made as in the first instance and no further trouble was experienced.

It should be mentioned that an attempt was made to grind the bearings from the black stock; that is, without taking the chip over the body. This was found at that time to be no economy, the scale on the steel causing the wheel to fill up and become glazed; this occurred so frequently that the diamond had to be applied very often to dress the wheel and only 57 per hour could be ground. Later experience has proved that either pickling the pieces or using a grade or half-grade softer wheel would have overcome the trouble and might have given more profitable results.

FRENCH ARSENAL WORK

Tenders were asked for by a French naval arsenal for a plain grinding machine to grind the gun and shaft shown in Figs. 61 and 62. The Norton Grinding Company tendered for this job along with other firms. The specification was that both gun and shaft were to have 1 mm. removed by grinding to have good surface finish and to pass gages provided, these gages gave a tolerance of 0.02 mm. plus for the shaft and 0.25 mm. plus and minus for the gun. The gun, the Norton Grinding Company guaranteed to grind complete in 45 minutes, and for the shaft it guaranteed a time of 45 minutes. The Norton Grinding Company got the order and the machine, an 18×96-in. electric driven self-contained, was delivered and set up. There were

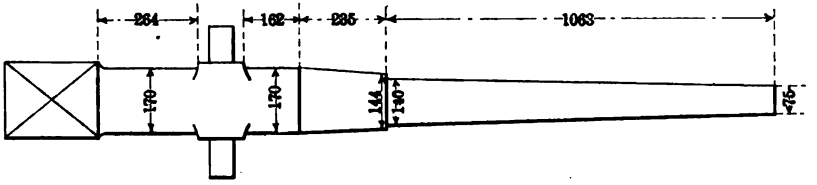


FIG. 61.

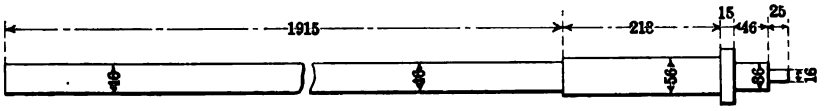


FIG. 62.

FIGS. 61 AND 62. GUN AND SHAFT TO BE GROUND.

only two guns prepared for grinding, so that all experience of the job had to be gathered from grinding the first one; this occupied a time of 75 minutes but note was taken of the graduation marks of the swivel table when set for the tapers, as some precaution for the future against losing time in finding these tapers. One universal steady rest was fixed on the portion to the left of the trunnions, another near the muzzle and a third where the two tapers meet.

The gun was first rough ground on either side of the trunnions, then the table was swung over and the steep taper roughed and after this the long taper was roughed, the table first being readjusted to suit; the amount left for finishing was about 0.05 mm. The wheel was now trued up nicely and the long taper finished to gage, next the short taper, then the table was set at zero and the parallel portion finished, the total time being 41 minutes.

GRINDING SHAFTS

There were four shafts to be ground and after grinding two to get some practice it was decided to have the time test on the third. The first shaft had occupied 95 minutes and the second 62 minutes, so that there was some 17 minutes

to pull up. Five universal steady rests were used equally distributed along the shaft and the larger diameter was first roughed down to within 0.05 mm. of finished size; the same was done with the longer portion and after truing up the wheel this same part was finished to gage and the shaft turned end for end in the machine; the two shorter diameters were then finished by forming cuts, also the collar, and the larger diameter last, the whole shaft being completed in 40 minutes. A 24L Norton allundum 2-in. face wheel was used in both cases running at 6000 ft. per minute. The side feed or travel of the work in both examples was 5 ft. per minute, this being the fastest feed on this particular machine. For the shaft (machine steel) a work speed of some 30 ft. per minute was given but for the gun 55 ft. was given, as it was of somewhat harder material and really required a softer wheel.

A WIRE WOUND GUN

Using about the same speeds and with a similar wheel another type of built-up wire-wound gun was ground on a Norton 18×168-in. machine which gave very satisfactory results; the A or inner tube was ground in 2 1/2 hours, it being necessary to use 21 separate gages for variations in diameter. This job was of interest from the fact that the diameter had to vary every 5 in. from 0.001 to 0.002 in., this to correspond with the bore of the shell to be shrunk on. The wire winding was afterward ground, and here it should be said that grinding was found to be an immense advantage over turning in this operation. The grinding of this occupied 1 hour. The last operation was grinding the built-up gun, which was done in 2 3/4 hours, removing about 1/32 in. of material from its diameter. The length of the gun was about 13 ft. and the total time for grinding was 6 1/4 hours as against some 50 hours in the lathe for the same work, with the advantage in the grinding machine of a superior job.

EUROPEAN CAR AXLES

For the finishing of railway passenger-car and wagon axles, as well as locomotive axles, the grinding machine is now considered an economic necessity, at least so far as Germany is concerned, and has in fact been almost made a feature of the contracts made with the Prussian state and other Mid-European railway companies. The fact that nearly all these companies are state owned and have in each case appointed inspectors to supervise their work in each of the factories, calls for and insures a more highly finished axle than is usually the case with private railway companies who have their own plant. In fact some of the points they insist upon regarding as necessary would perhaps appear as absurdities to the more practical American or Englishman, but when we consider that many firms in various parts of the country are engaged in this industry the high grade of accuracy demanded seems more reasonable; for instance, an axle produced in southeast Germany may possibly at some time have to be run in boxes made in the northeast of that country or some remote part of Europe.

Several attempts had been made to grind these axles previous to the year 1904 but although the results obtained were highly satisfactory the cost was thought to be too great as compared with the ordinary method of finishing with hand tools, which by the way was the common method and was speedy and cheap. In that year a large concern in the Düsseldorf district put in an 18 × 96-in. Norton plain grinder as an experiment, and the results were so gratifying that a "repeat" order resulted and two years ago this firm was producing 1000 axles per month with the two machines and have probably improved on that in the intervening time. The superiority of the ground surface of the journal over that which had previously been obtained by hand work was in itself a recommendation to the appointed inspectors but the greater uniformity of sizing was still more so and resulted in pressure being put on other makers to fall into line.

A WHEEL SHAPING DEVICE

It was at first the practice to grind the parallel portions of the axles only, then to return them to the lathe where the radii or fillets were cut out by hand

FIG. 63. RADIAL TRUING DEVICE, ON 10-IN. MACHINE.

tools; now it is the general practice to grind the fillets also with the saving of much time and altogether more satisfactory results. For forming the required curve on the wheel the Norton Grinding Company provide a neat fixture with their machine which is shown in Fig. 63. In view *A* is the diamond tool, *B* is the swinging frame in which the diamond tool is held, *C* is the set-screw for hold-

ing the diamond. *E* is the handle of a plug which is inserted in a taper slot in the swinging frame whenever the fixture is desired for truing the face of the wheel. When radial truing is done, this plug is withdrawn. *F* is a hole in the axis of the swinging frame in which a stud is inserted that is used for setting the radius of the diamond point. This swinging frame revolves on ball bearings in order that there may be no lost motion at any time; these ball bearings are adjustable to take out all lost motion. For whatever radius is required to be formed a stud must be turned of a corresponding diameter which fits in the axis of the fixture. The diamond is first clamped in position with its point touching this stud, the stud may then be removed and the wheel turned to shape.

METHOD OF HANDLING AXLES

It may be of some interest to describe the manner in which the axles are ground and the general machining, which is as follows, as practised by one of the most modern plants: The forged axles are first rough turned in special lathes which grip them in the middle and the journals, wheel seatings, etc., are rough turned by a tool at work at either end; about 0.5 to 1 mm. is left for removal by grinding and a coarse feed is used for turning, the fillets being turned approxi-

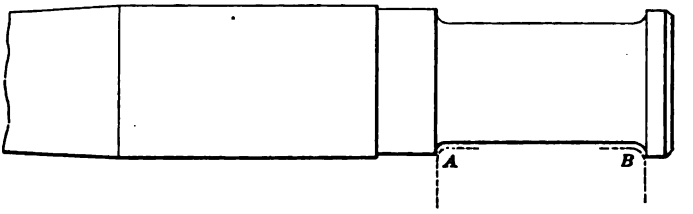


FIG. 64. CAR AXLE GRINDING.

mately to shape. In the same lathe the axles are cut to length and then taken to another machine to be recentered; for this purpose the journals are run in roller steadies and centered in the usual way, the axle being driven direct by a belt from the overhead works. In the grinding machines the wheel seating is ground with roughing cuts to a fixed size (and it is found an advantage to leave this surface as coarse as possible for the pressing on of the wheel), the dust-proof seating is next rough ground, also the collar on the end of the axle and then we proceed to grind the journal. In the Norton plain grinding machine the table stops may be so arranged that the table trips automatically about 1/16 in. short of the point from which they are set which is an especial advantage in this class of work. In grinding these journals the stops are set as dead stops so that the wheel cannot pass beyond the width of the journal as shown by dotted lines in Fig. 64, at the same time when traversing automatically it trips a little short of this distance. The journal is first roughed down to within 0.05 mm. of finished size by the automatic feed and then the face of the wheel is nicely trued

up, after this the journal is nicely finished to size (care being taken to note the position of the ratchet wheel when down to size), the wheel is then moved back and the table brought up by hand to the dead stop, radius *A* being formed first and then *B*, feeding the wheel steadily into a point which it occupied in grinding the journal. It is then allowed to take one chip across the journal to match up with the forming cuts at either end, and after this the dust-proof seating and collar are just touched up and the axle is finished.

SURFACE FINISH OBTAINED WITH A FLAT GROUND PEBBLE

The steel from which these axles are usually made is of a quality which will not take a high finish by the ordinary methods, but by just glazing the wheel slightly with a flat ground pebble a fine luster may be obtained. This must be applied very lightly or the wheel is likely to be put slightly out of truth, or else cause slight chatter marks on the surface of the work; a pebble ground to shape may be used to dress the radius on the wheel.

Axles of the size shown have been ground at the rate of four in 2 hours 10 minutes, including all the handling and changing over and there is good reason to believe that the pace has been accelerated by the operators of two separate firms. In one factory at least the suggestion was acted on of cutting off the axles to one dead length, also centering them to one depth by means of a dead stop on the centering machine spindle. With this arrangement, which entailed no extra work, there was no necessity to set the stops for every axle as had previously been the case, and some little percentage of time was gained; it also simplified the gaging and resulted in a much more easily duplicated form of axle.

ANOTHER SHAFT JOB

Here is a little job that caused a considerable amount of trouble of a sort that is by no means uncommon: The small shaft shown by No. 1, Fig. 65, was a detail in some textile machine and put through in batches of 200 at a time. The shafts were of machine steel made from the bar in a turret lathe leaving 1/32 in. on the diameter for finishing, the 1-in. portion being afterward case-hardened, and they had to be interchangeable as regards size on the largest diameter within 0.00025 in. to fit an annular ball bearing. It had been the practice to straighten the shafts first and then finish the hardened portion by grinding in an old lathe with a grinding attachment fitted to the carriage, the soft portion being afterward finished in the engine lathe. By way of increasing the production a 6×32-in. plain grinder was put in for finishing both this and other work and the trouble that ensued was caused by a little change in the order of operations on this particular job.

The operator (an enthusiast in his business) got a batch of 250 to grind and with the best of intentions laid himself open to make a record as to speed. He

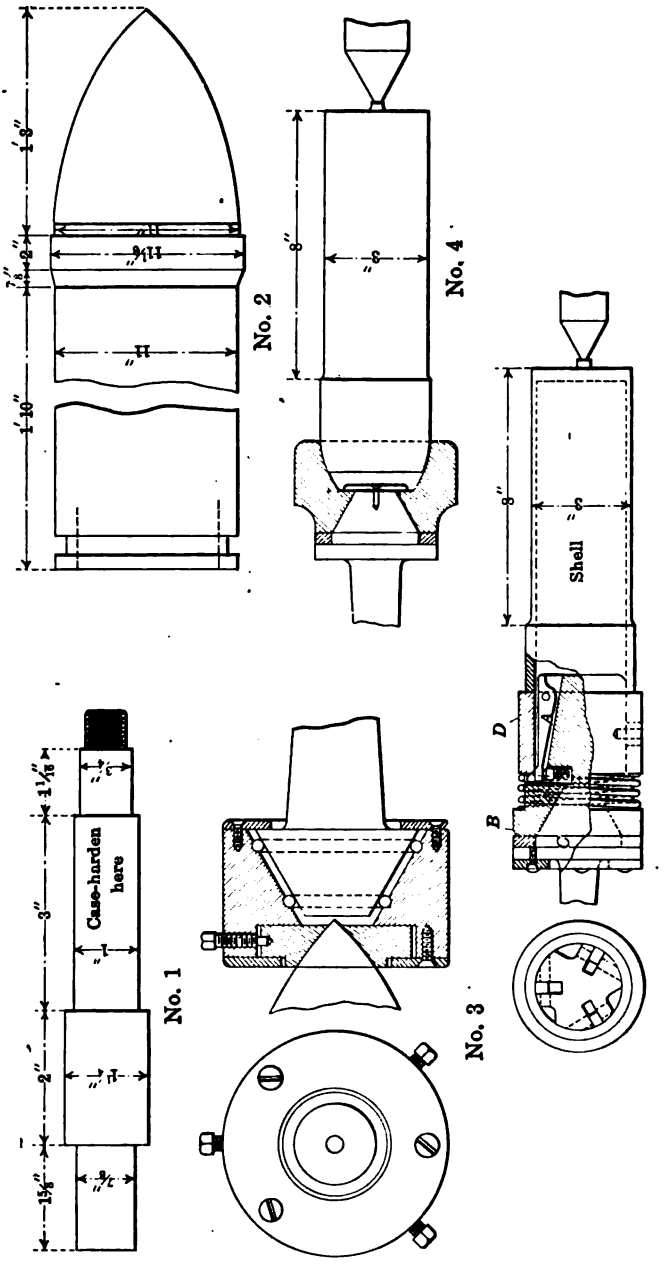


FIG. 65. GRINDING SHAFTS AND SHELLS.

commenced by roughing down the largest diameter to within 0.0015 to 0.002 in. of finished size using the automatic feed. He had provided himself with a pair of driving dogs and while one was in process of roughing he affixed and unfixed a driving dog on another one, getting through at the rate of one per minute. When all had been roughed down on this part he treated the hardened portion the same way at the rate of 30 per hour following up with the two ends; these he roughed by means of a forming cut coming down to a fixed point on his index wheel, his time being some 40 seconds each.

TROUBLE AT THE FINISHING POINT

He trued his wheel up nicely and commenced to finish the hardened part, and afterward the two ends, by the same methods of feed as for roughing and taking a similar time, but found to his dismay that some 50 per cent. of the shafts would not clean up on the largest diameter. The reason, of course, was that he unthinkingly commenced on the job the wrong way and should have roughed the hardened portion first when all or most of the hardening strain would be removed. However, we all obtain our education by failure to some extent and both the operator and his supervisor recognized this. Since this occurrence he has revised his mode of procedure on many similar jobs and always attacks a hardened portion first; these particular shafts he is now getting out at a rate of 60 per day of 10 hours.

PROJECTILE AND SIMILAR WORK

In the manufacture of projectiles, guns, etc., the grinding machine has come to be considered a very great economical factor. Its adaptability for rapid and accurate sizing makes it of peculiar value in the shrink fits which are a feature of modern artillery; wire winding when it exists is more easily ground than it can be turned and even the outside finish of a gun is more easily obtained by grinding than by any other means. Rifle barrels both for military and sporting purposes are now common food for the grinder in most establishments for the sizing and finish on their outer diameter, the peculiar curve of the latter being obtained either by an adjustment of steady shoes or by a former bar of the requisite shape. Both of these methods are modern features of the Norton machine which enable a tube to be accurately ground in 3 to 4 minutes.

GRINDING SHELLS

Since the introduction of the higher-grade steels for the making of projectiles, grinding even in its primitive form has long been found an economic necessity and in the Sheffield (England) district the sandstone wheel has long been in use for the purpose, consuming an enormous amount of power and with a painfully

limited grinding capacity. For hardened shells grinding is, of course, an absolute necessity and the means employed to grind one or two types of the shell may be of interest, this especially as the chucking appliances may be usefully applied for other purposes.

Number 2 shows a shell of large size which is hardened from the point well up to its ring and is ground on an 18×96-in. machine in an average time of 18 minutes. It is driven by means of a three-jaw chuck which grips the interior of the bore, the chuck being fitted with a plug to enable it to run on the headstock center; the other end of the shell is supported on a ball-bearing revolving center, No. 3, which has an adjustable shoe. This latter feature is found necessary because the points generally distort in hardening and it is a ready and convenient means of setting the shell true. Some 0.020 in. is ground from the diameter of the shell and the wheel is turned to form the small cone by means of a special device fitting on the footstock. The point of the shell is smeared with loose emery powder to insure its having a positive grip in the adjustable shoe. There was some little tendency to chatter in this job and this was attributed to the limited bearing surface. It is proposed that balls be dispensed with on the cone and a similar bearing to that for the smaller shells be provided with the addition of a ball-thrust collar. The chatter was overcome by fixing a wooden steady rest against the revolving center bush which acted as a cushion for absorbing the slight vibration.

SHRAPNEL CASES

Number 4 is a type of shrapnel shell made in a hydraulic press. The shells are first rough turned in lathes of a special type where about 1/32 in. is left for removal by grinding and 25 per hour are ground in a 10×50-in. machine. The method of driving may be clearly seen. It consists of a revolving bushing running on a center pilot fitting in the headstock. The pressure of the supporting center insures proper drive and the shells are placed in position and removed without halting the work drive. The driving dog (not shown) is fixed on the larger diameter of the bush. A similar size of shell but of different type is shown by No. 5. Here the method of driving is, of course, different but the output is the same. The bore is not machined and is somewhat out of round but the variation from size does not exceed 0.010 in. The drive is obtained from three triggers *A* fixed in a revolving steel bushing on a center plug *C* fitting in the headstock. The triggers are serrated and are expanded by means of a hardened sliding bush *D* which is rounded at the corner of the bore and which presses on the tapered heel of the triggers when the shell is placed in position; light springs below the heels of the triggers cause them to contract when the pressure is taken from the supporting tail center. Some little slip invariably takes place here when grinding commences but it is only momentary and the drive is found to be

quite efficient. It will be noted that the corner of the revolving bushing is rounded so as to facilitate the chucking and removal of the shells after completion.

LIMITS AND FINISH ON THE SHELLS

The broad limit of 0.002+ and − is allowed on these shells which somewhat explains the rapid grinding; finish again is of no moment as they are afterward painted and as they are made of a hard quality of steel it is some trouble to get them rough enough to suit requirements. It has been found that scoring the wheel occasionally with the diamond by hand, taking care to keep the wheel face flat, will give the corrugated appearance wanted and as the wheel wears smooth the process of scoring can be repeated. On the other hand some governments go to the other extreme and as they nickel plate their shells they demand a high finish which, of course, lessens the production somewhat.

In these methods of chucking work there is an excessive amount of tail-center pressure involved and a white-lead paste mixed with a few grains of graphite is found an excellent center lubricant, it answers well where heavy weights are carried either in the lathe or grinder and jobs weighing a few tons have been run some 6 hours, without a sound being heard from the centers, the latter having the appearance of burnished silver when the job was removed.

MISCELLANEOUS OPERATIONS

Some miscellaneous examples of cylindrical grinding in addition to those shown by Mr. Derbyshire are illustrated in Fig. 66. On the piece shown at *A*, 0.220 in. was removed from the diameter at a surface speed for the work of 28 ft.; traverse movement of wheel 2 1/4 in. roughing, 1 1/2 in. finishing; wheel feed, 0.013 in.; wheel used, carborundum, 2 1/2×18 in., grade 36 N, O D bond; material, chilled iron; time complete, 6 hours; number of cubic inches removed per minute to finished surface, 0.53.

These rolls were ground from the rough and given a high finish with a limit of variation of 0.0005 in.

At *B* the material was chilled iron; removed from the diameter, 0.032 in.; time, 90 minutes; surface speed of work, 30 ft.; wheel used, American corundum, 24×3 in., grain 60, grade J; wheel traverse, 1 1/2 in. per revolution of work; cubic inches removed per minute to finished surface, 0.40 in.

In grinding chilled-iron rolls where an extremely high finish is required, it is sometimes necessary to give the grinding wheel a somewhat smaller traverse movement and this movement is sometimes as small as 1/2 in., when using a wheel 2 in. in width.

By the foregoing examples it will be seen that wheels of a comparatively soft grade were used, which is good practice in grinding hard material, the standard rule for selecting grinding wheels being, for hard metal a soft wheel, and for soft

metal a hard wheel. It is believed that in grinding soft metal too much has been expected of hard wheels, for to grind economically a wheel must wear in order to keep sharp and free cutting, and, by the example shown at *C*, it will be seen that while the wheel was of a softer grade than generally used, the results were excellent.

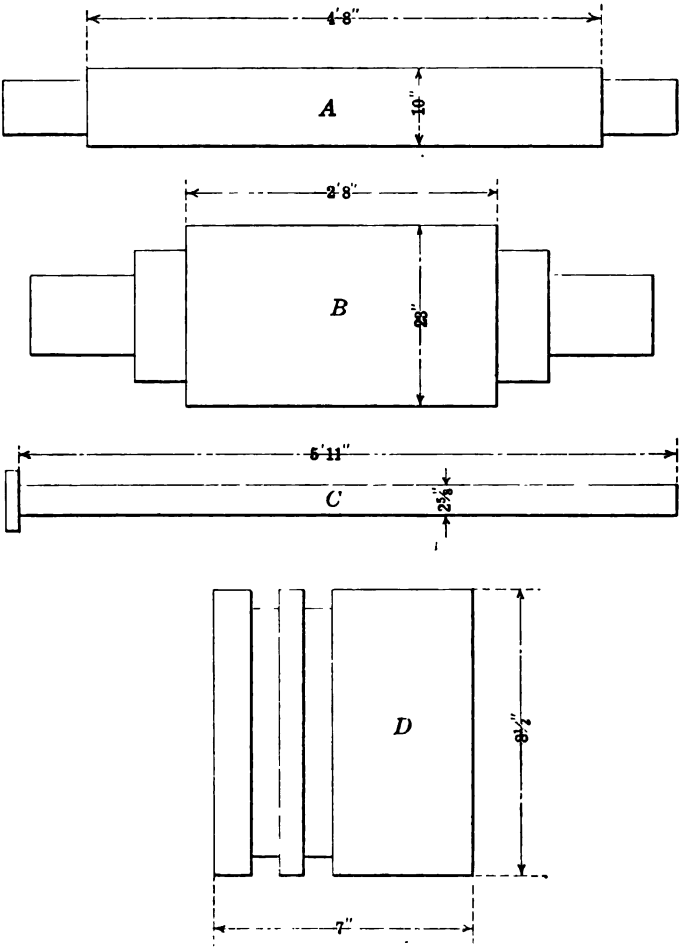


FIG. 66. VARIETY OF CYLINDRICAL WORK.

On the piece referred to, 0.075 in. was removed from the daimeter, the material being soft steel; time, 40 minutes; limit of variation, 0.00025 in.; wheel used, Aloxite, grade 303 O, bond D 496; wheel traverse, 3 in. per revolution of work; surface speed of work per minute, 15 ft.; cubic inches removed per minute to finished surface, 0.54.

This work was roughed down to within 0.003 in. of finished size, no difficulty

being experienced in getting the work to run perfectly true, which can be attributed to the fact that by using the soft wheel a good, free-cutting action took place, and that spring rests were used, which allowed the work to center itself as it was freed from internal strains. It is also very important that a spring tension be used in connection with the tail center to allow longitudinal changes in the work while being ground.

The gas-engine piston shown at *D* was finished in one operation, it being only necessary to true the grinding wheel after grinding every seven or eight pistons. The material was cast iron; surface speed, 80 ft. per minute; wheel used, carborundum, grade and grain 403 P, bond O F, size 2×24 in.; wheel traverse, 1 7/8 in. per revolution of work; removed from diameter, 0.040 in.; cubic inches removed per minute to finished surface, 0.40 in.; time, 9 minutes.

By comparing the above methods to those employed a few years ago, it will be found that they are far superior by reason of the decrease in amount of time taken to get the results, which is made possible by the modern grinding machine, embodying all the features that go toward rapid production of work of a superior quality.

In general practice, work should be finished in one operation, but this cannot always be done, depending greatly on the quality of the job. When grinding work in two operations, it is always advantageous to grind close to the finish size in the roughing operation, allowing just enough on the piece to insure its truing nicely.

GRINDING SMALL DRILL ROD PIECES

In experimenting with different wheels in the grinding of the small, soft Stub's wire rod, as shown in Fig. 67, it was found that a 24 combination, grade K, Norton alundum wheel was too hard. The piece would continue to spring in

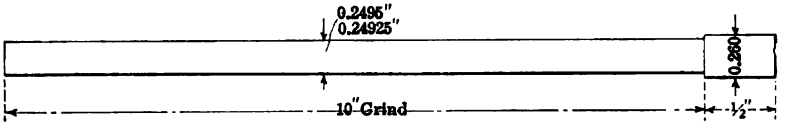


FIG. 67. GRINDING SMALL DRILL ROD.

such a manner as to give the operator a lot of trouble so that it required 20 minutes to grind each piece. A 46-grain, grade I wheel was substituted and the pieces were produced in 3 minutes each. In the latter case, the free-cutting wheel allowed the operator to attend to the business of grinding instead of to that of juggling.

GRINDING A ROLL

The halftone, Fig 68, shows a chilled cast-iron roll 20 3/16 in. diameter by 28 in. long, ground by J. H. Hollinger on a Landis 20×96-in. roll grinder,

removing 1/4 in. from the diameter of the body only. The surface speed of the roll, roughing, was 52 1/2 ft.; finishing 52 1/2 ft.; traverse of wheel for each revolution of the work, 7/8 in.; wheel feed at each reversal, 0.006 in. for roughing; 0.001 in. for finishing. This roll was ground with a 22 9/16 in. carborundum wheel having a 2×8-in. hole, 403 P., Bond O. F., running at 925 revolutions, 5472 surface feet, and it was reduced in diameter 19/32 in., which is a cost of 90 cents. This wheel wore just fast enough to keep itself sharp and, for roughing, was only dressed once with the diamond. The time for grinding the roll to

FIG. 68. GRINDING CHILLED CAST-IRON ROLLS.

a smooth finish, good enough for hot rolling, was 4 hours; total cubic inches removed, 221; cubic inches removed per minute to finished surface, 0.92 in. The motor used on this work was a variable speed 25 horse-power. Average horse-power consumed, 21.

Mr. Hollinger does not believe there is much, if any, difference in wheel contact when it comes to producing a high finish. For example, if it requires 15 minutes to grind a high polish on a piece of work 1 in. in diameter, to grind a piece of work 12 in. in diameter, the same length, should take twelve times as long, or just 3 hours, using, of course, the same peripheral speed. It seems reasonable that if a large piece of work is to be given the same bright finish as a smaller one, the amount of times the wheel passes over one point must be taken into consideration.

GRINDING ROLLS UNDER STEAM PRESSURE

Figure 69 shows how the rolls for textile machines are ground so as to be true in actual operation. These drums are made of heavy piping having the heads forced into place and when in use are heated by steam to the required temperature.

Knowing that this heating distorts the roll to some extent, the Curtis & Marble Company, Worcester, Mass., turn and grind these rolls under the same steam pressure at which they are run in service. This engraving shows how the steam is admitted to the roll through the bearings at the end, the steam gage and all the connections.

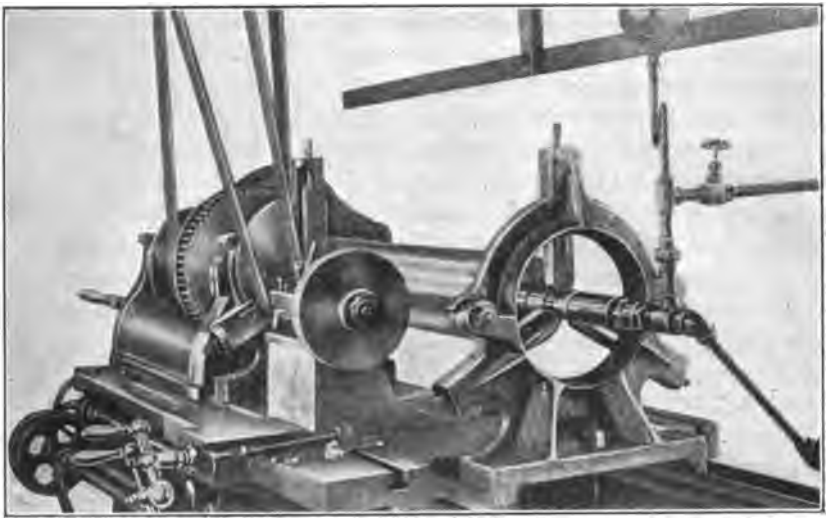


FIG. 69. GRINDING ROLLS UNDER STEAM PRESSURE.

FORM GRINDING

Form grinding is believed by some who have given the matter long and careful study to be the cheapest method of finishing work if proper care is taken of the wheels and the work. It is not the easiest way nor can it be done with the cheapest men, but it pays in dollars and cents when the men are trained to handle it as it should be.

A very narrow wheel traversed across the work requires the least attention as the wheel need not be kept as true or in as good shape as with the wide wheel. But a wheel having a face wide enough to do the work without traversing will do the work quicker and better if the machine is heavy enough and the wheel kept in proper order.

The wider the wheel the more cutting points we have at work and the more work can be done in a given time. It is almost identical with the use of forming tools in screw machine or turret work and formed cutters in milling work. In either case the cutting tools must be kept in shape and kept sharp which is just what must be done with a grinding wheel. While it is probably not advisable

to use wheels having forms of as intricate shape as in the case of form tools of steel, owing to the difficulty of maintaining the form while truing and sharpening the wheel, the keeping of the wheel in shape is less difficult than might be imagined. The only difference between this and tools of steel is that we can sharpen the tools by grinding on the flat face while in this case we must sharpen by truing off the formed face. And this can be done much more easily than could be done with steel cutters if they had to be sharpened in this way.

Then too it is well to remember that, instead of wearing away as rapidly as we are apt to think, a grinding wheel wears less in grinding a bar from end to end than a steel tool does cutting a chip from the same bar.

But form grinding does not necessarily mean the grinding of fancy shapes and applies to plain grinding as well as any other, when the surface is ground by the wheel being fed in and not being traversed with relation to the work. In other words, when the ground surface depends on the shape of the wheel, whether it be a plain cylindrical surface of one diameter, be shouldered with several different diameters, or be given round corners or other shapes desired.

Crank pins and crankshaft bearings for automobile and other engines are frequently ground in this way, especially the crank pins, and the wheel retains its shape much longer than might be considered possible.

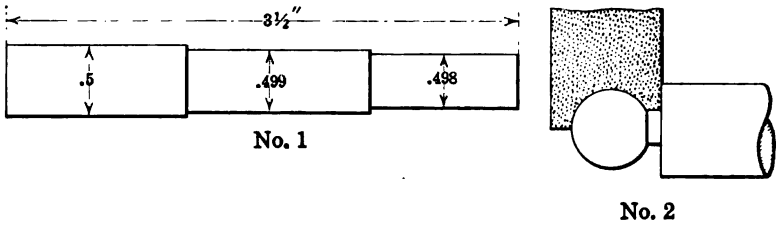


FIG. 70. EXAMPLES OF FORM GRINDING.

They are often ground from the rough forging, the roughing wheel leaving about 0.04 in. for finishing. The roughing wheel will grind from 4 to 16 pins at one truing and the finishing wheel will finish from 6 to 24 pins at one dressing. The difference depends mostly on the operator and the way he handles the work.

A few examples of form grinding from actual practice may be of interest.

The small pins shown in No. 1, Fig. 70, are about 3 1/2 in. long and 1/2 in. in diameter, having three diameters. The ends of these are bearings and the center diameter is a drive fit. They only vary about 0.001 in. from one to the other.

The wheel is dressed so as to give these diameters and there is no difficulty in maintaining the sizes. The wheel is simply fed into the work and grinds a large number of pieces at one truing.

Another and perhaps more difficult piece of work is shown in No. 2, where a ball is ground on the end of a shaft. The shaft is formed in a screw machine

and finished after hardening, by the form wheel shown. This is a more difficult shape to maintain on the wheel but it is done without difficulty, the radius being turned out with an ingenious little holder which swings the diamond in exactly the right path.

A very different and much easier proposition is the grinding of the outside of a number of ball races at one operation by the use of a widefaced wheel as shown. This is a very practical application of the principle and one that can be widely adopted with little difficulty. The main requirement is to get a machine which is stiff enough to stand the power necessary to do the work without springing.

The fear that the wheel will be worn in ridges and require frequent truings that will waste the wheel, is entirely unfounded. The cost of the wheel is one of the least items of expense when the cost of labor is considered with relation to the work done.

One of the largest propositions in this line is the axle grinder of the Norton Grinding Company in which the car-wheel seat and the journal are to be ground by a form wheel. These are to be done at separate operations, as in repair work, the journal is the only part that needs to be repaired.

This means a wheel having a face of 10 1/2 in. which will true up the wheels by feeding straight into the journal until they are round. It is expected that these will not require truing more than once a day and that this will mean the grinding of about 100 axle journals in that time.

This form of grinding seems sure to develop widely and it is well to consider its application when narrow work can be done in duplicate, or broad surfaces are to be ground. An example of this is the grinding of cutting edges of reamers on a widefaced wheel fed directly into the work.

CHATTERING AND THE USE OF STEADY RESTS

Mr Norton's observations reprinted below on the development of the grinder, the phenomena of vibration, the application of steady rests, etc., form a very interesting feature of the present chapter:

The phenomena of vibration have been probably the most puzzling to all of us who have been more or less familiar with cylindrical grinding for the last 25 years, or since the introduction of the "universal grinding machine." They are still the cause of much, if not the majority, of the misunderstandings that arise between wheel maker, wheel user, machine maker and machine user.

A short study of the evolution of the grinding wheel and the grinding machine may aid us in understanding the various phenomena that have caused us so much trouble. The first universal grinding machines were driven from one shaft overhead and the work was driven from a pulley of the same diameter as that which drove the wheel. As near as we can estimate from the relative size of wheel pulley and the work pulleys, the work ground on centers must have rotated about 1000 and 2000 per minute. As the work then ground ranged from 1/4 to 2 in. diameter, we find a surface speed from 130 to 520 ft. per minute.

At that time the "emery wheel" was always very tough—in fact, was a cutting tool only when "hacked" or rubbed with great force. It is evident that impressions of speed of work were created by the fact that slower work speed caused burning of the work and "glazing" of the wheel. We must also remember that this early work was ground dry and that there was an effort made to run the work fast enough to distribute the heat equally around the work, with the belief that equal distribution would prevent bending. The wheel being tough required that the work should rotate very fast in order to rub the surface sufficiently to allow cutting. As there was not sufficient power in the wheel driving belt to allow of deep cuts, this rubbing or sharpening of the wheel had to be done by great speed of the work.

The traverse of the work past the wheel was at first about 0.01 in. per turn of the work, and to get to the end of a piece of work in reasonable time required rapid rotation of the work. The fact that in our early experience we removed an infinitesimal amount of stock at each pass made it possible to grind without large chatters. All the earlier work, however, would show chatter marks when lapped in a ring.

REDUCTION IN WORK SPEEDS

Following those early machines came the knowledge that wheels were, or could be, made of different grades and that softer grades cut more freely. With this freer cut came the experience that they wore away rapidly unless the work rotated slower; so gradually we ran the work slower until 80 to 100 ft. per minute was reached for nearly all sizes and all kinds. At that point we remained for a long period, and many still insist upon retaining about that speed.

With small and narrow faced wheels we were enabled to grind without difficulty and the narrower the face the less trouble we had. Owing to this fact we for a long time used 1/2-in. wheels with the face narrowed to 1/16 or 1/8 in. and were content until some one a little more courageous than the rest ventured to use the "full width" of the 1/2-in. face and also ventured to arrange the traverse faster per revolution until 1/8 in. was reached. This met with opposition from operators but finally, in the face of this opposition, it was retained. With it came trouble from vibration or "chatter," and then began long experimenting with wheels as to their relation to chatter marks. When we got chatters we changed wheels until we ground without marks and the poor "wheel maker" was made responsible for our trouble. When by selection of wheels we could grind good work, there came a still greater increase in traverse per revolution until 1/4 in. was reached. This met with opposition, but remained in some cases. With it came more trouble with chatters.

RESTS AND HEAVIER MACHINES

Then came experiments with steady-rests. Rests had been used always, but not on all work—in fact, on but very little of it, and then but one rest and

that very light. With these experiments came many forms of rests until many spring rests covering practically all of the length being ground were used on each piece of work, and we could grind good work with the full width of a 3/4-in. face wheel and a 1/4 traverse in extreme cases, 1/8 being used more commonly; the work still running at about 100 ft. per minute.

Next came an effort to produce still more work by grinding, and heavier machines were made with wheels 3/4 in. and 1 1/2 in. faces and a maximum traverse of about 1/2 in. to the revolution of the work. With this greater trouble from the chatter and much better rests were made to steady the work.

Next came a very heavy machine with wheel 2-in. face, very heavy spring rests, work speed from 80 to 90 ft. per minute and a traverse of about 2 in. per revolution. This gave a larger output, but a continued effort to increase the output produced chatters, which were overcome by throwing out the springs and using rigid rests. Then again came dissatisfaction with the amount of work being done, and radical changes were made with wheels. This gave still more work, but with the increased work came a return of chatters. Next came experiments with slower work speeds, and the chatters disappeared, while the product was increased.

CHANGE IN SPEEDS AND WHEELS

At the present time the best and quickest work is done at a work speed from 6 to 40 ft. per minute, a wide range of surface speed of work proving necessary to high quality and large production. With this the wheels have grown coarser, softer and fewer in number of varieties, until at this time the quickest work and finest finish on soft steel is produced with a grade "L" wheel, No. 24 combination, grade "M" being used in few cases. A few years ago 8c grade "M" or "N" was the common thing.

A few years ago great care was taken to select a wheel that would not chatter; now no thought is given to this feature of the wheel, but rather the work speed is adjusted to each case, while the wheel remains the same for a wide variation in material, shape and size of work.

The reference above is to experience in our own works. Many still insist that they must rotate the work faster than we do and that they must use finer and harder wheels. If they retain the high speed of work they must also retain the finer, harder wheel; one cannot exist without the other.

Chatters are of two kinds—one a series of flat spots or lines parallel with the axis, the other a mottled marking, sometimes a spiral and sometimes irregular. The first is the result of vibrations of the work, which is caused by the wheel and work acting together during the grinding. There are perhaps a number of forces that play a part in producing the result, but we cannot at present name them, or explain their action. It is sufficient at present to know that vibration of the work is caused by the cutting of the wheel. How do we know

this? Remember that we have for years selected wheels that would not "chatter"; that we for a long time turned away part of the wheel face to "make it grind steady," and that to-day, with all other factors the same, some wheels will chatter while others will not.

SOME ILLUSTRATIONS

The following case will serve to illustrate: A piece of machine steel, about 4 ft. long and 1 1/2 in. diameter, was rotating on the centers of a grinding machine, no steady rests in contact. A coarse wheel was used to grind it; no chatter marks could be obtained. Another wheel somewhat finer was used, and the work was covered with chatter marks. These marks when counted proved to be 7 to the inch of circumference. A deeper cut was taken and the marks showed 10 to the inch. A slight cut was taken, and the marks showed 16 to the inch. The table traverse was changed and the marks showed 32 to the inch. This was done all with one speed for the work. A change of work speed showed as many different marks per inch, until a speed was reached at which chatter marks were impossible. The use of steady rests enabled grinding without chatter at a faster speed than was possible without them.

The vibration shown by lines parallel with the axis is always the vibration of the work independent of the surrounding or supporting machine. It is caused by the wheel at the point on the work where the wheel is cutting, even though the axis of the wheel and the headstock and footstock may remain perfectly rigid. This vibration may be transmitted to the centers, and it may, if the machine is poorly designed, be transmitted to the heads and finally to the entire machine. Vibrations may show on the work when there is absolutely no vibration of any part or parts of the machine.

Vibration of the work is never shown by spirals, mottles or spots; but always by lines parallel to the axis. Work may be vibrated by the wheel cut no matter how large or short it may be. In case of heavy work the vibration is transmitted to the center points, and the number of vibrations per rotation of work is affected by them. This is where the rigid steady rest comes in; it serves to connect the heavy work to the entire table along its entire length, like resting it on an anvil.

NECESSITY FOR RESTS

Long, light work is easy to hold steady while grinding; but heavy, "stiff" work is the most difficult to grind rapidly without chatters; therefore it should always be supported by the best and the most steady rests, because of the weakness of all center points. We need steady rests with slim work, because it is more slender than the center points and vibrates in spite of them. We need steady rests with heavy, "stiff" work, because center points are often not heavy enough to hold it steady.

To assist rapid grinding the center holes in the work should be as large as practicable, in order that contact may be on as large a surface of the center as possible. We are often told by grinders that they have no use for steady rests on heavy work and that they have no trouble with chatters with high speed of work and fine wheels. If all such were to grind with a wide wheel face and produce more work per minute, they would discover that as the product is increased the necessity for changes in handling would increase. It is all very nice to settle upon a method that will produce good work to-day; but we are not supposed to reach that point where we can be satisfied with our product, but must continually increase it. The history of chattering shows that it has been common to all types and makes of machines when the conditions were right and that it has increased in proportion to the increase in product; that it has been overcome by changes in wheels, adoption of steady rests and reduction of work speed, and that these things have produced similar results in all types and makes of machines.

GEARING DOES NOT PRODUCE VIBRATION

The later and heavier grinding machines are arranged to rotate the work through gearing, and many who are not familiar with the facts have supposed that vibration of the work was caused by the tooth action of the gears. If this were the fact it would be impossible to change the pitch of the lines by a change of wheel, change of cut and change of speed. It would also be still more impossible to grind without marks without steady rests at any and all speeds by selecting both wheel and work. Another point in this connection is this; the gear which drives the work is loose upon a heavy fixed stud, while the center upon which the work rotates is fixed in this heavy stud and this center does not rotate. With lathes, as we know, the conditions are the reverse. The gear, spindle and center are one, revolving in an oil bearing, and if there be motion the work must follow it.

There have been much time and money spent on foundations for grinding machines, when the cause of trouble was vibration of the work itself independent of the machine and its resting points.

THE MOTTLED SURFACE

When work shows a mottled, or mottled spiral surface, the cause may be vibration of any part of the machine caused by the motion of the wheel, the jar of a heavy belt joint or an unbalanced wheel.

A well designed and constructed machine, however, should be so rigid and self-contained that the axis of the wheel and work will remain in constant relation whatever the vibration of the machine or floor, unless in case of a wheel out of balance; when, if the machine is placed on a solid foundation, there would

in some cases be a jar that would cause the axis to change relation enough to show a mottled surface. Another cause of mottled surface is a wheel and spindle too light and running loose in the bearings.

Another case of mottled spirals is a wheel too hard for the work, or one having an uneven cut on its surface.

The mottled and spiral surface is not known with the more modern heavy machines when the best wheels are used.

When work has vibrated enough to show on the surface it has produced an irregular surface on the wheel and the wheel must be trued off before smooth work can be ground, even though the work may be so supported or changed in speed as to prevent further vibration.

RIGID STEADY RESTS

Ideas as to the proper method of making steady rests naturally vary widely, some contending that a spring rest is the only proper method while others maintain that a rigid rest gives best results. Advocates of the solid rest contend that, where the pieces being ground are not heavy, it is quite probable that no practical difference can be found. Where the piece weighs less than the rests supporting it, the spring is practically solid. Where the work is heavy, every blow of the wheel tends to spring the work away from it. Where the work is not round, this is a serious fault as it does not take out the high spots.

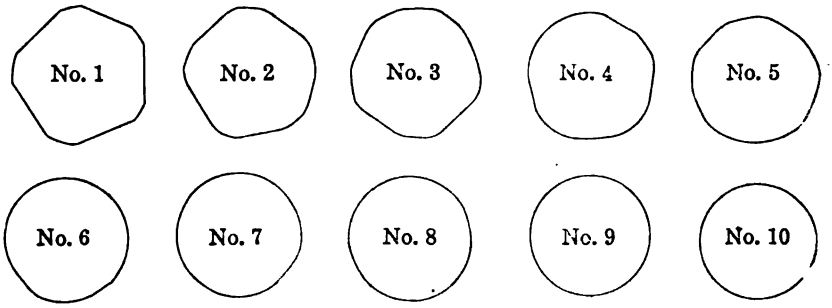


FIG. 71. GRINDING WITH A RIGID REST.

With a solid rest, the high spots are bound to be ground away and many believe this is the better form for all except very light work.

An interesting experiment along this line was tried by C. H. Norton.[1] Taking a round shaft, he had it ground to an irregular five-sided shape as shown in No. 1. This was then put in a grinder with a solid rest of the proper size, the work being entirely supported by the rest and not by centers. The remaining nine numbers show the different stages of the grinding operations, each suc-

[1] In connection with Mr. Nortons explanation of the question of rests in the preceding pages the illustration in Fig. 71 will be of interest.

cessive step getting nearer to the round. The rest was changed as occasion demanded, and the last number shows a round shaft, showing that the solid rest does support the work firmly and properly so that inequalities can be ground out. With a spring rest where the work can jump away from the wheel, those who have made a study of this question claim that the results are not as satisfactory where the piece must be trued up by the wheel.

SPEEDS ON THE GRINDING MACHINE

In an article on grinding speeds H. F. Noyes gives the results of some interesting experiments as follows:

The question of proper work speeds on the wet-grinding machine has always been open to discussion, and shows a diversity of practice, both among operators and in the recommendations of the machine manufacturers. This has originated in part from variations in the cutting qualities of the wheels. All operators know that wheels of presumably the same grade and grain will not always cut alike, and that different bonds often require a variation in speed; so that quite a diversity of speeds may arise, according to the kind of wheel the user has become accustomed to.

This variation in wheels is much less now than it was formerly. Within the past few years manufacturers have been able to duplicate wheels quite closely. This fact, coupled with the experience gained by the machine manufacturers themselves, has gradually crystallized the practice for general work along two lines; one is a comparatively slow work speed, with a traverse nearly equal to the width of the wheel, and uses a soft wheel and slow wheel speed; while the other involves a higher work speed, shorter traverse, harder wheel and higher wheel speed.

The question chiefly affecting wheel speed is that of safety, for it is a foregone conclusion that other things being equal, more work can be obtained with the higher speeds. Just where this speed should stop depends on the construction of the wheel, its shape and the provisions for protection. The safe limit is usually recommended by the maker. Common practice is to limit this speed to 6000 ft. per minute rim speed for machine grinding. Some manufacturers of machines recommend speeds of 7000 ft. and even of 8000 ft., and as the wheels are usually tested at 9000 ft. these speeds are probably not excessive, provided the wheel is a plain disk, without a recess, and of strong bond. The wheels usually used at these speeds are in connection with the second of the two practices mentioned, and are combination wheels which are harder and stronger than the wheels used for the first-mentioned practice.

It is recognized that a variation in the contsruction of the wheel must be made to grind different materials, and this feature will sometimes influence the wheel speed. The proper wheel for any material is usually given in the makers' catalogs. As a general proposition, however, harder materials require softer

wheels. Recessed wheels, with the clamping or fastening ring located within the recess, are necessarily weaker; their speeds should be limited to 6000 ft. This is particularly the case with the thin wheels used for crank grinding, where the wheel must be of large diameter in order to gain clearance for the cheeks of the crank. For these wheels 5500 ft. is probably a safer limit. All wheels should be carefully handled in being changed on the machine. Probably in the majority of cases where a wheel breaks, the real cause is an incipient crack which was caused by careless handling or by allowing the wheel to run against a shoulder when in use.

A study of the other speed conditions necessary to obtain the greatest output from a grinding machine brings out many possible combinations, and it is often hard to pick out the best without considerable experimenting. These are the items which enter into the combination; the speed of the wheel, the grade of the wheel, the surface speed of the work, the traverse of the wheel or work per revolution of work, and the depth of the cut. As stated before, the two general lines of demarcation are, a softer and usually wider wheel, slower wheel speed, slower work speed and greater traverse; as compared with a harder and narrower wheel, higher work speed and shorter traverse.

RELATION OF CUT AND FEED

The depth of the cut bears an inverse ratio to the traverse in either case, and can be increased, in general, without changing the results, provided the traverse is correspondingly decreased. It usually happens, however, that with the same grade of wheel, better sizing conditions and less wear of the wheel are obtained by lessening the cut and increasing the traverse. These general statements refer chiefly to roughing out, and to obtaining an ordinary commercial finish. To obtain a fine finish a higher work speed and smaller traverse are desirable.

Getting to the question of actual speeds for the work in these two combinations, there is a wide latitude. The first combination uses as a basis an average work-surface cutting speed of about 20 ft. per minute, and often much lower, 10 and even 5 ft. being suitable in some cases for roughing out. For finishing, specially where a fine finish is required, a faster speed is desirable, up to about 40 ft., which is about the highest to be recommended for these conditions. This speed is suitable for wheels of a grade of 30 to 46 on soft steel; a harder grade is needed for cast iron. A traverse of from two-thirds to almost the full width of the wheel is suitable for these conditions.

The second combination calls for a work-surface cutting speed of 60 to 100 ft. per minute, a traverse up to about one-half the width of the wheel, and a grade of wheel of 46 to 60, for the average line of work. A study of tests which were made from actual working conditions in the shop, made, however, for another purpose, will bring out some of these points. The basis of comparison was the amount of metal removed per minute. The amount of power required was recorded; one interesting point which was demonstrated was that the

amount of power required to remove a certain amount of metal per minute was practically the same, regardless of the size and type of machine; that is, that the horse-power used per cubic inch of metal removed per minute was approximately the same, regardless of the machine. It was about 4 horse-power for cast iron and 10 horse-power for steel. Of course the power required to run the machine light varied with the size of the machine; but when this was subtracted, the net horse-power required for removing the stock bore a regular relation to the amount and kind of metal removed per minute.

While these experiments were made along the line of the first mentioned set of conditions, they brought out some interesting points in regard to its limitations. One of these was that for cast iron, the best results in the way of removing metal were obtainable with a slower traverse, deeper cut, and preferably higher work speed.

RESULT OF TESTS

The conditions and results of thirteen tests are shown in Table 5.

In this table compare test 1 with tests 2 and 3. These tests were taken on a small machine about 10×30 in. In 1 and 2 all conditions were the same, except the traverse and the depth of cut. The increase from 0.5 cu. in. of metal removed per minute to 0.8 showed a distinct advantage for the slower traverse, without any particular difference in the wear of the wheel. In the third test an increase in the work speed was also made, which apparently gave the same result, but showed more wear of the wheel. Tests 7 and 8, with all conditions the same, except the wheel speed, show the distinct advantage to be gained by increasing the speed of the wheel. The speed used in No. 8 is toward the safe limit, however, considering the construction of the wheel, and would hardly be advocated for regular practice.

Experiments 9 and 10 vary only in surface speed and depth of cut. They were made on thirty pieces, and show absolutely no difference in results. The same is practically true of tests 4, 5 and 6. The fourth used a slow traverse and high surface speed; the second a high traverse and slow surface speed; the third a high traverse and higher surface speed. Experiments 11, 12 and 13, though not comparative, were made on the same machine, and show what can be done in the way of removing metal. Experiment No. 11 is a lively record.

The deductions which have been made from these and other experiments are, that a great number of work speeds is not necessary, provided they are arranged so that certain desirable limits can be obtained. Take, for example, tests 4, 5, 6, 9 and 10. They show conclusively that the same results can be obtained with practically a wide range of speeds, if a proper combination is made with other items.

Let us consider a plain grinding machine with a swing of say 12 in. This would be considered suitable for a regular run of work up to 3 or 4 in. in diameter, and for occasional jobs of larger size. In arranging for the speeds we

Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Wheel grade.....	46 L	46 L	46 L	60 M	60 M	60 M	46 K	46 K	36 L	36 L	36 L	24–36 3½	36 L
Dia. × face.....	10½ × 1½	10½ × 1½	10½ × 1½	13¾ × 1	13¾ × 1	13¾ × 1	13⅞ × 1	13⅞ × 1	17 × 2	17 × 2	19½ × 3	24 × 3	24 × 3
Wheel surface speed.	4950	4950	4950	6840	6840	6840	5440	6890	5340	5340	4080	5026	5026
Wheel wear.....	0	0	0.005	0.040	0.050	0.055	0.020	0.025	0.003	0.003	0	0	0.032
Work length × dia.	10½ × 2	10½ × 2⅛	10½ × 2	17 × 1⅜	17 × 1⅜	16½ × 3½	17 × 2	17 × 2	10¼ × 1½	10¼ × 1½	19½ × 3	19½ × 3	20½ × 3½
Work material....	C.I.	C.I.	C.I.	Soft steel	Soft steel	Soft steel	Soft steel	Soft steel	Soft steel	Soft steel	C.I.	C.I.	Crucible steel
Work surface speed	39 ft.	42 ft.	60 ft.	35 ft.	12 ft.	35 ft.	22 ft.	22 ft.	12 ft.	6 ft.	9 ft.	31 ft.	11 ft.
Trav. per rev. of wk.	1 in.	3/16 in.	3/16 in.	¼ in.	1 in.	1 in.	1 in.	1 in.	2 in.	2 in.	2⅛ in.	⅝ in.	2⅛ in.
Depth of cut.....	0.004 in.	0.013 in.	0.010 in.	0.004 in.	0.004 in.	0.004 in.	0.002 in.	0.025 in.	0.003 in.	0.006 in.	0.030 in.	0.020 in.	0.010 in.
Total reduction...	⅛ in.	⅛ in.	⅛ in.	1/16 in.	1/16 in.	1/16 in.	1/16 in.	1/16 in.	1/32 in.	1/32 in.	⅛ in.	3/32 in.	3/32 in.
Time.....	8 min.	5 min.	5 min.	10 min.	9 min.	20 min.	20 min.	12 min.	2 min.	2 min.	2 min.	2¼ min.	4 min.
Cu. in. material r. p. m.	0.5	0.8	0.8	0.3	0.3	0.26	0.16	0.26	0.31	0.31	5.5	3.5	1.8

TABLE 5.—TESTS OF GRINDING WHEELS

will assume that for each size of work from 3/4 in. to 5 in., we would like to have surface speeds of approximately 10 ft., 20 ft. and 40 ft. per minute. Such a range would be sufficient for all practical purposes and conform to the best practice. With six work speeds of respectively 10, 17 1/2, 31, 54, 94 1/2 and 165 revolutions per minute, each speed being 75 per cent. greater than the previous, we can get very close to the desired surface speeds for almost any diameter of work within the range mentioned, as shown by Table 6.

Dia.				Nearest surface speed to 10 ft.	20 ft.	40 ft.			
½ in.	1¼	2	3	7	12	21	.....	.....	.....
¾ in.	2	3	6	10	18	30	.....	.....	.....
1 in.	2½	4½	8	14	24	42	.....	.....	.....
1½ in.	.....	4	7	12	21	38	64½	.....	.....
2 in.	.....	5	9	16	28	49½	86½	.....	.....
2½ in.	.....	.....	6½	11	20	35	61	107	.....
3 in.	.....	.....	8	14	24	42	74	130	.....
3½ in.	.....	.....	9	16	28	50	86	150	.....
4 in.	.....	.....	.....	10	18	32	56	98	172
5 in.	.....	.....	.....	12	22	42	72	125	220
6 in.	.....	.....	.....	16	27	49	85	149	152
7 in.	.....	.....	.....	19	31	57	99	172	303
8 in.	.....	.....	.....	.....	21	35	64	112	198
9 in.	.....	.....	.....	.....	23	40	72	118	222
10 in.	.....	.....	.....	.....	26	47	80	140	243
11 in.	.....	.....	.....	.....	28	51	88	153	258
12 in.	.....	.....	.....	.....	30	53	98	171	298

TABLE 6.—DIAMETERS AND SURFACE SPEEDS FOR GRINDING WORK

CHAPTER V

THE SURFACE GRINDER AND ITS WORK

Although the surface grinder has long been one of the most useful of our standard tools, of recent years it has become more and more important as a manufacturing machine and it is the purpose in this chapter to show some typical operations on several types of grinders of this class.

One of the principal papers presented before the American Society of Mechanical Engineers at the fall meeting, 1910, was by B. M. W. Hanson of the Pratt & Whitney Company, relating especially to the field and possibilities of the surface grinder. This paper and the engravings accompanying it contain so much information of interest and value that it is herewith reprinted nearly in full, as the opening section of this chapter, which illustrates certain types of surface grinders and some of the work for which they are especially adapted.

MODERN SURFACE GRINDING METHODS

The grinding machines now used can be divided into two large groups; machines for cylindrical grinding and machines for grinding flat surfaces. Cylindrical grinders are well known and have been highly developed by several machine-tool builders in this country. The other style of grinder, the surface grinder. is best known as a planer-type machine, with a wheel grinding on its periphery, and fed across the surface in much the same manner as a tool is fed across the surface on a planer or shaper. Another type is the vertical surface grinder with a cup-shaped wheel working in much the same manner as an end mill on a vertical milling machine.

In doing work on lathes or milling machines, it is comparatively easy to reproduce several pieces to the same dimensions by adjusting the machine to a size. This is possible because the reducing member, which is the turning tool, will resist wear for a considerable length of time without making any difference in the size of work. With grinding machinery this is more difficult, since the reducing member is constantly wearing away at a rapid rate. For very close work it is necessary to readjust the machine for every piece to be ground, which, of course, requires skill and time.

Devices now used control the size of the work, no matter how much the reducing members wear away. When the work has reached the desired size, which can be predetermined by suitable adjustments, the machine will auto-

matically throw out the feed and new pieces can be put in, one after another, and these will be automatically ground to practically the same diameter, say within one-quarter of a thousandth of an inch.

SURFACE GRINDERS

As said above, surface grinders have usually been made with the wheel grinding on its periphery and in some instances it may be necessary to continue to do work on this principle, as grooves and irregular shapes sometimes have to be ground and the thinness of the wheel makes it possible to get into narrow places; but when flat surfaces are wanted, the cup-shaped wheel has taken a foremost place in grinding. The wheel covers the whole width of the work at once and water is forced through the center of the spindle, centrifugal force throwing the water outward and compelling it to pass between the work and the wheel. It is astonishing with what rapidity work can be reduced to a flat surface under this process.

This method of grinding would never have been successful if it had not been for the advancement in wheel making. The wheel problem in connection with the machine has been most difficult. It has been found essential to select the right kind of wheel for different classes of work and for different materials. For grinding steel, either hardened or soft, corundum wheels have proved the best and for grinding cast iron the carborundum wheel has proved the best. The different degrees of hardness must be taken into consideration when the width of the surfaces to be ground varies.

The makers [The Pratt & Whitney Co.] are bringing out a much larger machine of this type than they have made before. This machine has a table stroke of 6 ft. and can grind a piece 6 ft. long and about 25 in. wide. It can also grind circular rings and disk surfaces up to 30 in. in diameter. The wheel has a diameter of 30 in. and the whole machine is driven from a single belt by a 40 horse-power motor. For such work as grinding guide bars, slide valves and link motions for locomotives, large stamping dies such as are used in electric works, facing automobile cylinders and automobile-engine frames, it is expected to show its superiority over any other method by several hundred per cent. In one of the trials, a surface of cast iron, 6 ft. long and 20 in. wide was reduced in thickness 0.01 in. in five minutes, leaving an excellent finish and an exact flatness. In fact when tested no point in the surface showed out of true more than 0.0005 in. In grinding steel this type of surface grinder produces chips that look very much like metallic wool, which seems to indicate that when a cupped wheel passes over the work the chips are made by the outer edge of the wheel in the same manner as chips produced by the outer edge of an end-milling cutter. If the chips were made underneath the broad contact surface of the wheel there would not be room for them to curl up in the small places which are left between each cutting particle of the grinding wheel. The large surface in contact with the work simply smooths the surface.

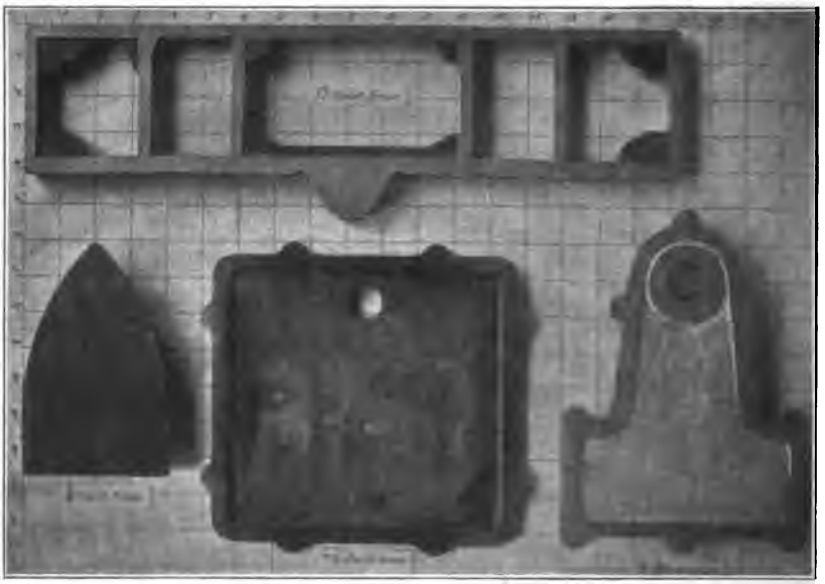


FIG. 72. EXAMPLES: NO. 1. CAST IRON, 15 TO 20 PER HOUR; NO. 2, CAST IRON, 60 PER HOUR; NO. 3, CAST IRON, 25 PER HOUR; NO. 4, ALUMINUM, 30 PER HOUR.

FIG. 73. EXAMPLES OF GRINDING: CHUCK PLATES, GROUND BOTH SIDES, 6-IN. 20 PER HOUR; 9-IN. 15 PER HOUR; 12-IN. 20 PER HOUR, VISES, GROUND ON TWO EDGES, TOP AND ONE END CLEARED ONLY, 20 PER HOUR.

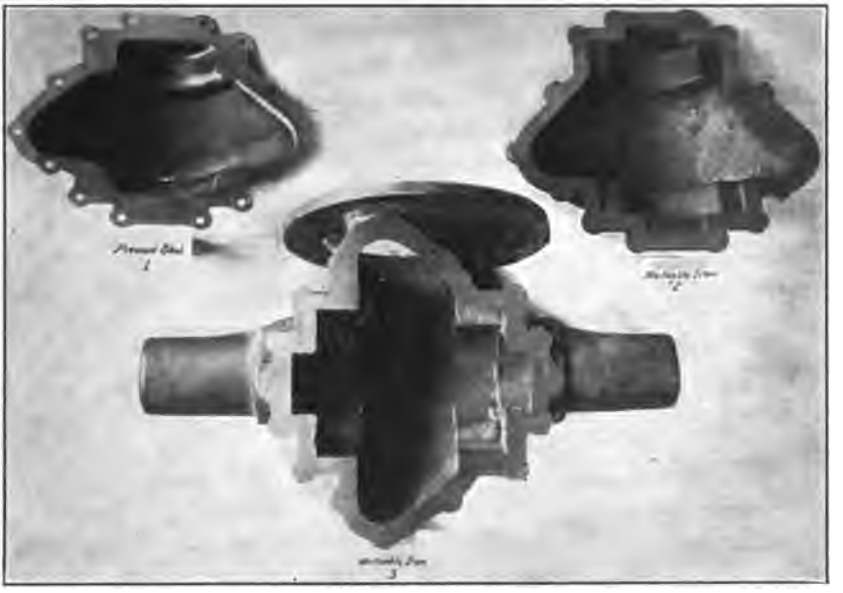


FIG. 74. EXAMPLES OF GRINDING: NO. 1, PRESSED STEEL, 15 PER HOUR; NO. 2, MALLEABLE IRON 15 PER HOUR; NO. 3, MALLEABLE IRON, 12 PER HOUR.

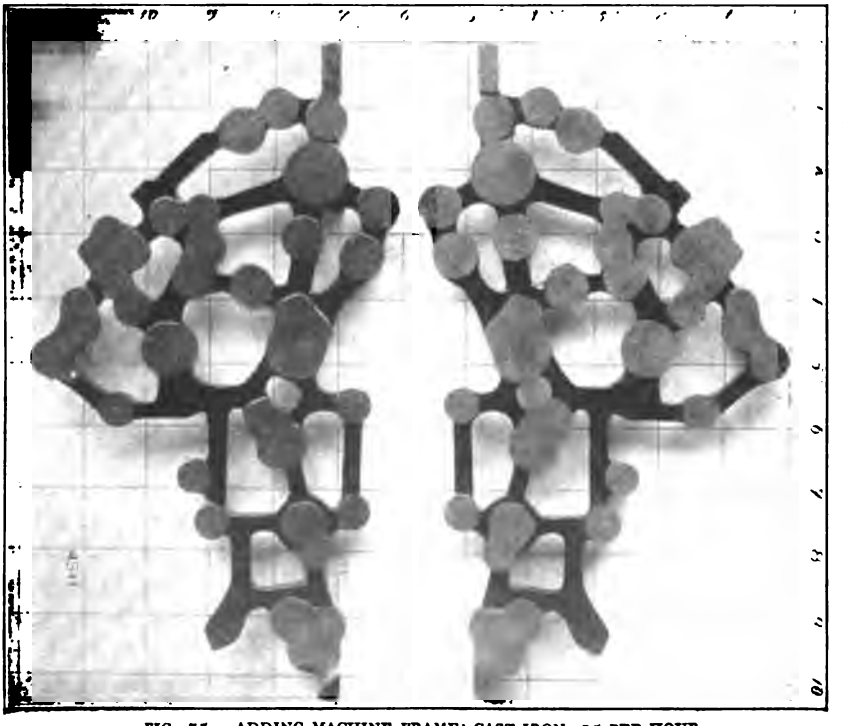


FIG. 75. ADDING MACHINE FRAME: CAST IRON, 15 PER HOUR.

The table on these machines is provided with different feeds. It is difficult to make an exact rule as to what feeds to use for different materials, but the operator can determine this by running the machine a few minutes. The difficulty lies in the fact that wheels supposed to be made of the same specifications, vary considerably and consequently the feed has to be regulated not only to suit the material being ground but also to suit the cutting ability of the wheel to be used. At the present time it is safe to say that grinding machinery is fully developed to the cutting capacity of the wheels and there will probably not be any essential changes until the grinding wheels have reached a higher development

EXAMPLES OF WORK DONE

In Figs. 72 to 75 several photographs are reproduced of work which has been ground on vertical cupped-wheel machines. In some instances, such as in the production of small gun parts, like hammers and triggers, the work has been done from 15 to 20 times faster than it can be milled, and it has a smoother and more accurate surface. This is especially true where the surfaces are not too wide.

SOME FURTHER EXAMPLES OF WORK ON THE VERTICAL SURFACE GRINDER

On the Pratt & Whitney grinder referred to in the above paper by Mr. Hanson, the wheel is presented to the work in the manner indicated by the engraving, Fig. 76, which shows the regular reciprocating table under the wheel. For certain classes of operations a rotary table is mounted upon the main table and revolved with the work under the wheel face.

Some further examples of work accomplished upon this machine in addition to those referred to by Mr. Hanson are illustrated in the engravings Figs. 77 to 79 inclusive.

The feed mechanism on this machine gives two table feeds which may be obtained while the machine is in operation through a gear box which is controlled by a lever at the front. The lever also serves as a means for starting and stopping the table.

The vertical spindle is so designed that the thrust is taken by a ball bearing, and the driving pulley which is at the top of the machine is mounted upon a hardened and ground bearing entirely independent of the spindle so that the pull of the belt is not transmitted to the spindle. The spindle is operated at one speed only. The spindle head is properly counterbalanced and it is accurately controlled through the feed mechanism, which may be operated by hand or automatically. Graduations enable the vertical movement to be accurately gaged, and provision is made for automatically disengaging the power feed.

The pump forces water through the hollow spindle to the interior of the

FIG. 76. PRATT AND WHITNEY 3-FT. SURFACE GRINDER.

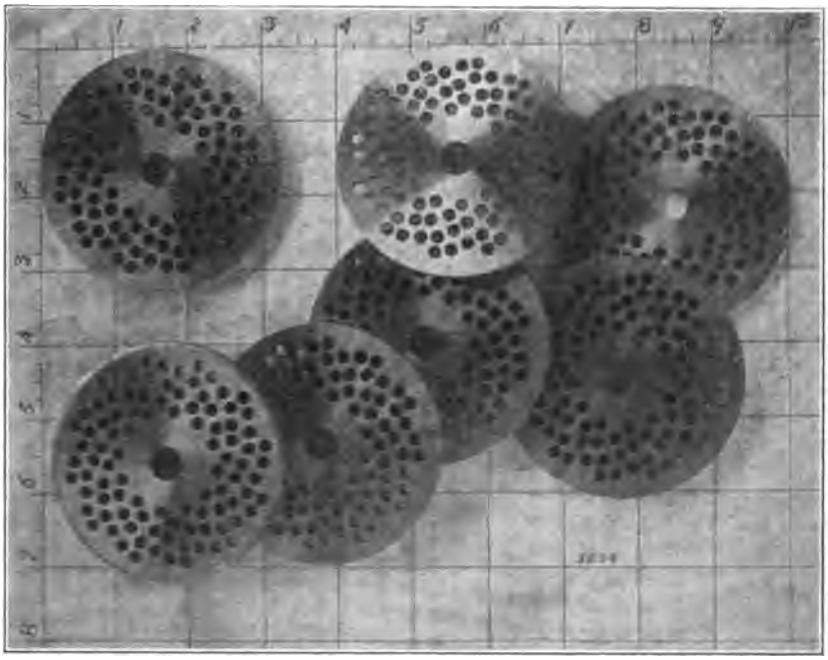


FIG. 77. MEAT-CHOPPER KNIVES.

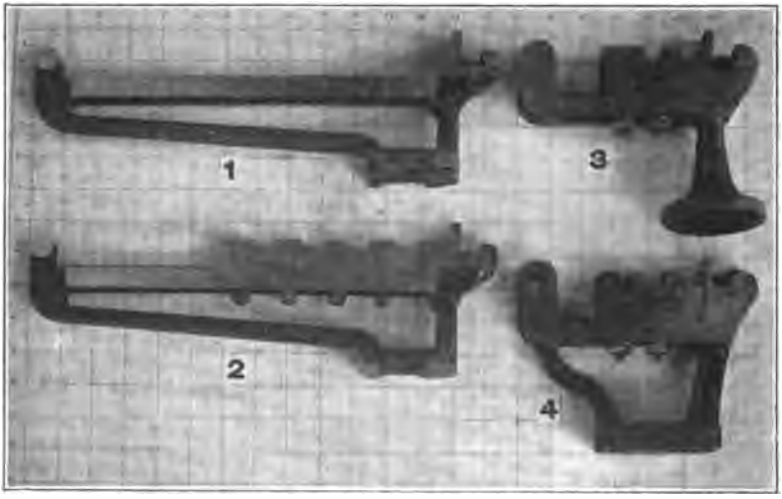


FIG. 78. SCALE PARTS: PIECE NO. 1, 25 PER HOUR; PIECE NO. 2, 25 PER HOUR; PIECE NO. 3, 25 PER HOUR; PIECE NO. 4, 25 TO 50 PER HOUR.

wheel where it is carried out by centrifugal force between wheel and work, to keep both cool and free from dust. Another stream is provided for the outside of the wheel and for cleansing purposes. The table is surrounded with a high guard within which the wheel operates, this preventing the escape of water. The wheel guard also aids in the control of the water.

The rotary chuck for use with a variety of work which is ground by revolving under the wheel, is driven by mechanism located outside of the water guard, making it impossible for water to enter the chuck. The chuck may be tilted to permit the grinding of concave or convex work, such as saws, cutters, etc.

Magnetic chucks both rectangular and rotary are used for holding various classes of work, and special holding appliances are also constructed to meet unusual requirements.

FIG. 79. SEWING MACHINE PLATES.

ANOTHER TYPE OF SURFACE GRINDER

The high-power vertical surface grinder built by the Blanchard Machine Company, Cambridge, Mass., uses a 24-in. rotary magnetic chuck for all classes of work, as indicated in the general view, Fig. 80. This chuck runs upon a ball bearing and is supported upon a sliding table which may be quickly moved clear of the wheel to place and remove work and returned under the wheel against a stop.

The spindle with its 16-in. cylinder wheel is driven by a 5-in. belt passing around the drum and under the idlers at the rear. The sliding head with the wheel spindle is let down on to the work by automatic feed, and power elevating mechanism enables the head to be run quickly up or down in making any desired setting.

The gearing for giving the different rates of table speed and the feed changes is contained in gear boxes attached to the side of the column, as shown in the engraving.

The machine swings work inside the regular guards up to 30 in. diameter. The chuck speeds range from 3.5 up to 30 revolutions per minute.

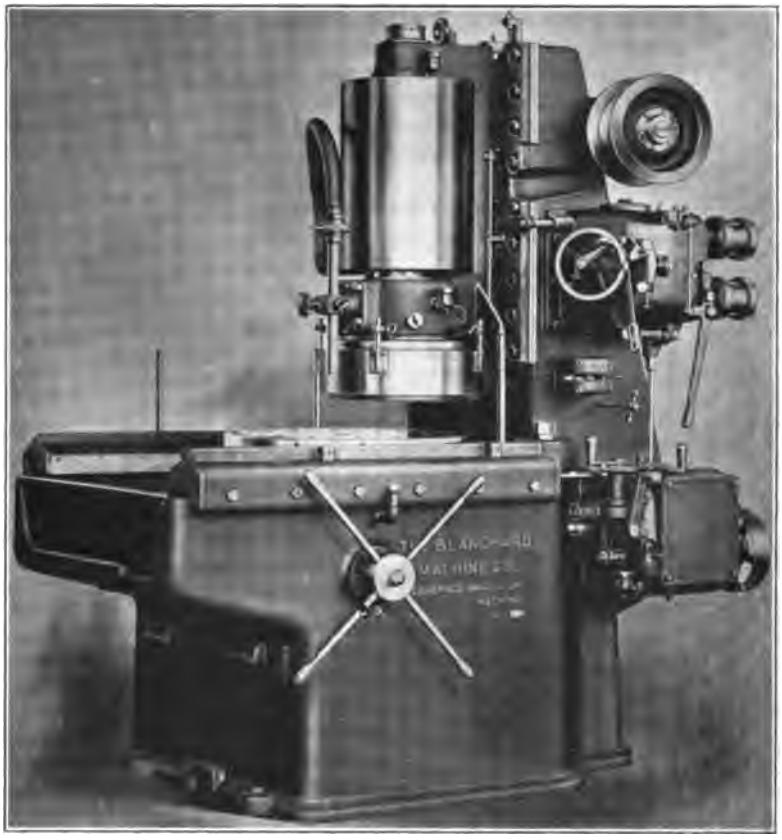


FIG. 80. BLANCHARD HIGH-POWER SURFACE GRINDER.

A recent development in connection with this machine is the application of a continuous reading caliper which is described by H. K. Spencer, as follows:

CONTINUOUS READING GRINDING CALIPER

The increased driving power and weight of the modern machine tool has made possible a large reduction in the time required for removing stock from the work, and naturally the other quantities involved in the total time per piece have relatively increased. The smaller the time for removing the stock becomes,

the greater, relatively, is the time required for measuring and for handling the work.

The Blanchard Machine Company, in developing its high-power vertical surface grinder, soon found that in many cases the time for removing stock was by far the smallest quantity included in the total time per piece. Magnetic chucking considerably reduced the handling time, but the need for a quick way of measuring the work thickness was imperative if the maximum economy was to be attained.

THE OBJECT OF THE DEVICE

The continuous-reading caliper has been developed to meet this need and has proved so successful that all Blanchard grinders are arranged to use this

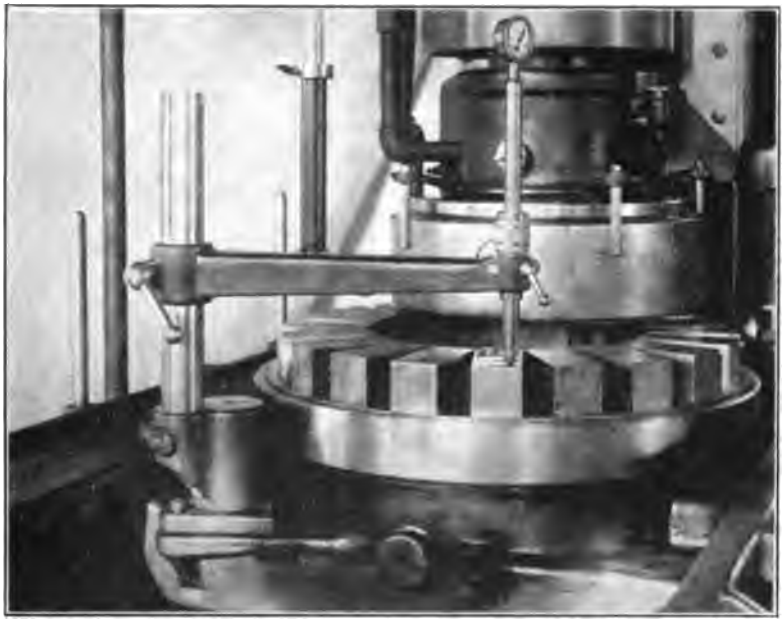


FIG. 81. CONTINUOUS-READING CALIPER ON BLANCHARD HIGH-POWER VERTICAL SURFACE GRINDER.

device as an attachment. Briefly, it may be described as a device which measures the work thickness continuously during the grinding operation, showing the operator by means of a dial the exact amount in thousandths of an inch by which the work exceeds finished size. The caliper is attached to the carriage of the grinder in such a position that the rotary work table carries the pieces which are being ground, alternately under the wheel and under the caliper, so that each piece is measured after every pass under the wheel.

In Fig. 81 the caliper is seen in the foreground with its contact point resting

on one of the steel blocks which are placed around the rotary work table in position for grinding. The 16-in. cylinder wheel of the grinder, surrounded by a steel safety hood, is seen at the rear of the table. Figure 82, which shows the parts in plan, will make clear their relative positions. When removing or placing work the table is moved out from under the wheel to the position shown in dotted lines, and the caliper, which moves with it, swings to one side, as shown leaving the table entirely clear.

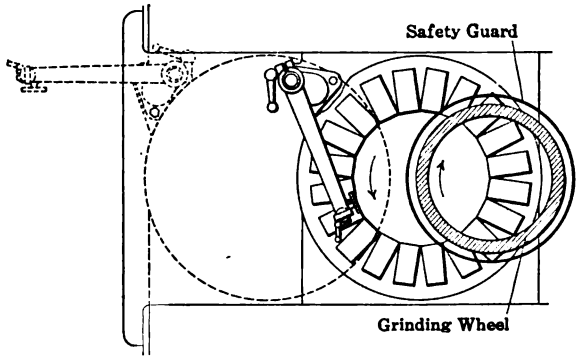


FIG. 82. DIAGRAM OF CONTINUOUS-READING CALIPER.

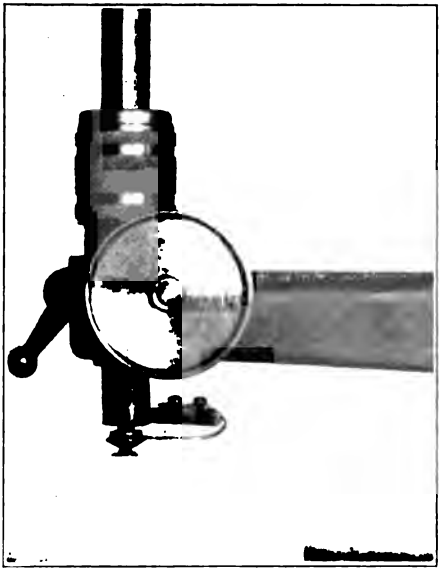


FIG. 83. THE CONTACT POINT OF THE CALIPER.

CONSTRUCTION DETAILS

The contact point on the caliper is seen in Fig. 83. The hardened steel button which rests on the surface of the work connects by a light rod inside the

vertical tube, with the Ames gage head seen in Fig. 81, at the top of the tube. Referring again to Fig. 83, the tube slides in a split sleeve, which may be clamped to it by the large nurled nut, seen just above the arm, and this sleeve in turn has a limited motion vertically, through the arm, controlled by a rack and pinion operated by the nurled wheel. This last motion is clamped by the small screw with the ball handle, seen at the extreme left in Fig. 83. These movements are simply for convenience in quickly setting the contact point after an approximate adjustment is made by sliding the arm up or down on the column.

SETTING THE GAGE

Figure 84 shows the dial-gage head used, which is graduated in thousandths of an inch. The dial can be revolved to set the zero graduation as required.

To set the caliper for size a finished piece known to be correct in thickness is placed on the table. After setting the arm about 2 or 3 in. above the surface of this piece, the tube is moved down, bringing the button in contact with the piece

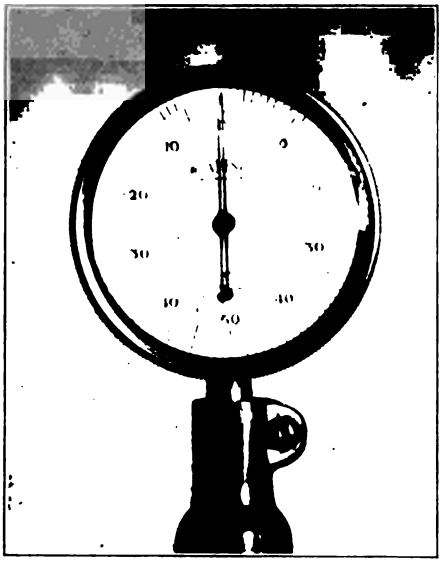


FIG. 84. THE DIAL GAGE HEAD.

and giving an indication on the gage. All adjustments are then clamped and the dial of the gage revolved until the zero mark coincides with the pointer. With the caliper set in this way, it will indicate zero when the work is ground to size, and if the work is oversize, the readings will show the excess stock in thousandths of an inch.

Readings are taken by the operator without interrupting the grinding. The caliper is simply swung over the work while the latter is revolving, and the

dial shows at a glance how much more stock to remove. The caliper may be brought into action as soon as the grinding begins and left there, giving a continuous indication, which approaches zero as the stock is removed; but this is not necessary, and considerable wear on the contact button can be saved by using the caliper only at intervals, until close to size. The wear of the button becomes appreciable only after several lots of pieces have been ground, and is readily compensated for by checking a piece in every fourth or fifth lot with micrometers, and setting the dial ahead an amount equal to the variation found. This applies to work where the limits are ± 0.001. For closer limits checking must be more frequent. The contact button can be easily replaced when worn.

THE ADJUSTABLE JOINT

A unique feature of the device is the adjustable joint between the fixed pivot in its base and the carriage of the grinder. A triangular flange is seated on a steel ball at its center and held down by three studs at the corners, so that by

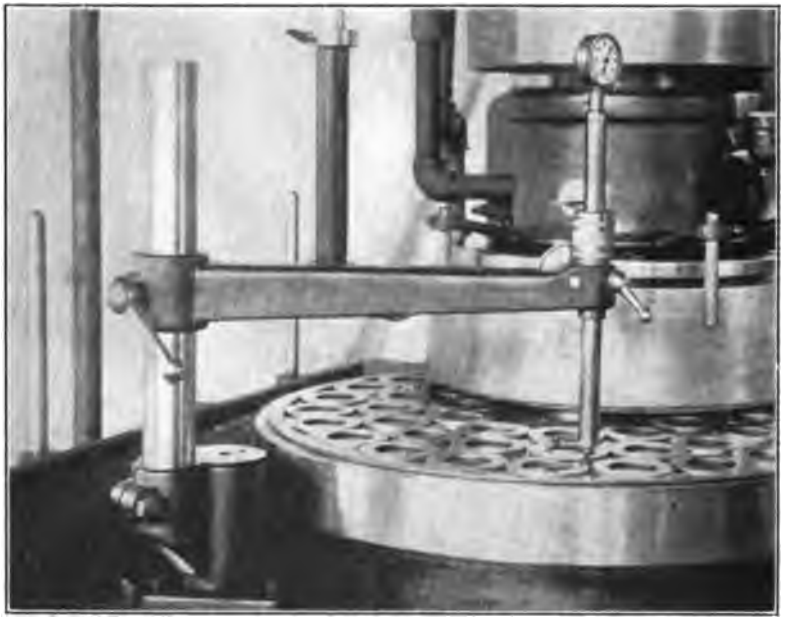


FIG. 85. THE CALIPER IN USE ON CAST-IRON WASHERS.

adjusting the nuts on these studs the axis of the pivot can be tipped in any direction. This is used to set the pivot perpendicular to the work table, so that as the caliper swings, the contact button moves exactly parallel to the table. The indication of thickness will, therefore, be the same, on a block of uniform thickness, at all points of its swing.

The pivot joint is cylindrical, ground and lapped to a close fit, and is entirely closed against the entrance of moisture or dirt. The vertical load is carried by a flat surface of hardened steel bearing on a hardened-steel ball placed centrally in the top of the pivot.

The tubular steel column may be unclamped from the base when the caliper is not in use, and since the pivot is in no way disturbed, the alinement will be correct when the caliper is replaced.

Figure 85 shows the caliper in use on cast-iron washers, and is used in the same way on gears. In this latter case, where the ground surfaces are very narrow, it is sometimes necessary to slow down the work table when measuring. With the all-geared table used on the machine this is easily done, and the whole operation of reducing the work speed, measuring and returning to normal speed occupies less than 10 seconds, during which time the grinding operation is not stopped, but goes on at a somewhat slower rate.

Experience shows that the average operator can work to limits of ± 0.001 in. with this caliper and that it reduces the measuring time practically to zero.

THE PLANER TYPE OF SURFACE GRINDER

The machine in Fig. 86 is the planer type of surface grinder built by the Springfield Manufacturing Company, Bridgeport, Conn.

This form of surface grinder, in which the wheel is carried upon a horizontal spindle, is built in several sizes, from small grinders intended for tool-room work, up to machines with a capacity for work 48 in. wide by 10 ft. in length. These grinders are built for a general line of work requiring surfacing, the one illustrated being adapted especially for tool-room work and small grinding in general. From the shape of the wheel and the nature of the contact, it is obvious that this type of grinder is particularly suited to the handling of work requiring grinding along grooved surfaces or finishing up to a shoulder.

This form of grinder is also built with an oscillating wheel head which is given a lateral movement that is simultaneous with the travel of the work under the wheel; the combination of movements passing the wheel across the work at many different angles to produce a fine finish and preserve the truth of the wheel. A very wide face wheel is used with this type of machine, and in the larger sizes of grinders the space between uprights admits of very wide work being surfaced.

On all these planer type machines provision is made for supplying a liberal quantity of water to the work and wheel.

The arrangement of the power feed for the head, the reversing drive for the table operating screw, and other features of importance are shown clearly in the halftone, Fig. 86. The magnetic chuck can, of course, be used for holding work whenever required.

THE VERTICAL GRINDING PLANER AND ITS WORK

Another type of surfacing machine built by the same concern is the Springfield-Brandes vertical grinding planer which differs from the design shown, principally in having a vertical spindle which carries at its lower end a large cup wheel.

Some of the work ground on this machine is illustrated in Fig. 87.

In this view, two tables are shown at *A* for a special grinding machine, which were ground right to a true surface and shipped without being scraped

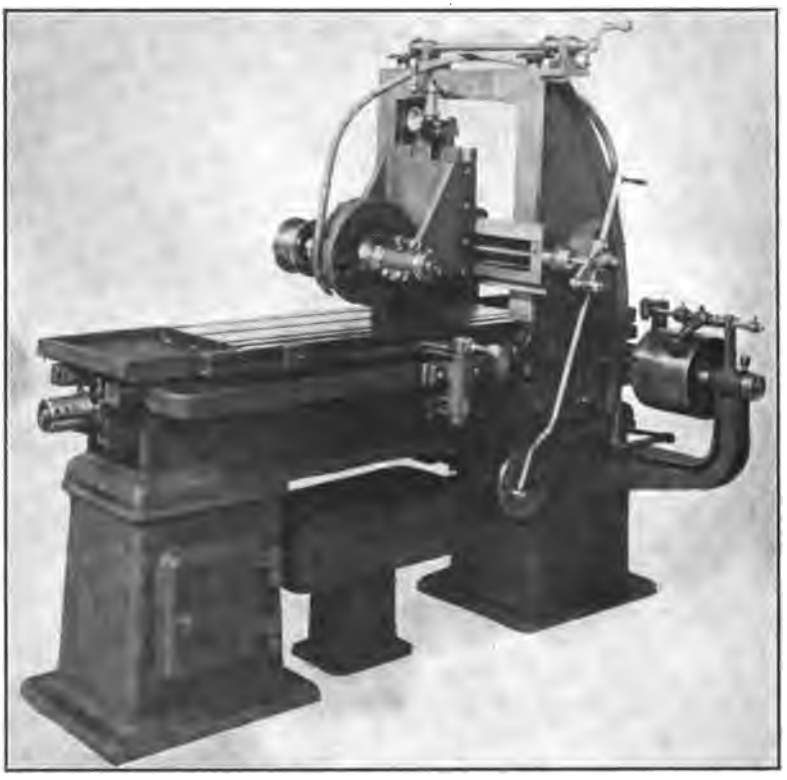


FIG. 86. AUTOMATIC PLANER TYPE SURFACE GINDER.

or fitted together. At *B* five sets of gear cases are shown as ground from the rough on the surfaces which fit together. The pieces average about 14 × 18 in. and the five sets were ground in about 1 3/4 hours.

The parts at *C* are some nuts used in the manufacture of grinders. They are ground from the rough on the two surfaces shown in about 2 minutes each.

Some bronze half boxes will be seen at *D*. These are used on marine motors and were ground in 3 minutes, from the rough.

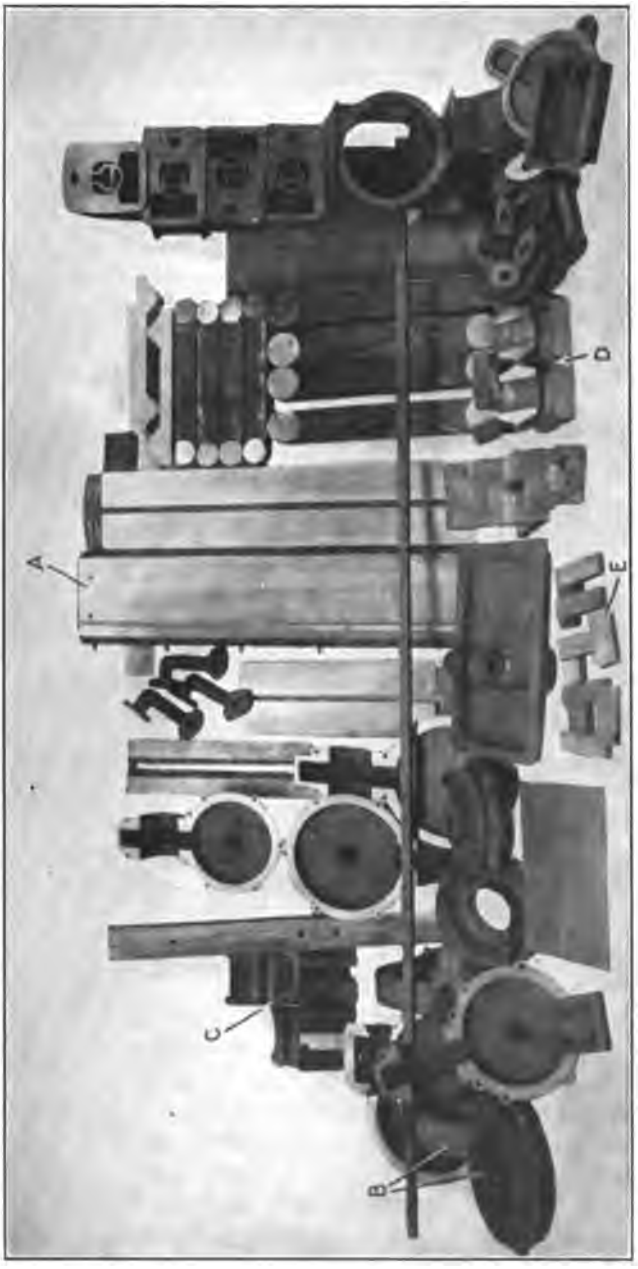


FIG. 87. WORK GROUND ON THE SPRINGFIELD-BRANDES VERTICAL GRINDING PLANER.

The dies at *E* were ground on one side at the rate of 50 in 10 minutes. These were rolled pretty closely to size so that it was only necessary to clean them, taking off on an average rather less than 1/64 in.

DISK GRINDING

The type of grinding machines known as the disk grinder and shown in Fig. 19, is growing in favor and is being used in a large variety of surfacing work. The disks are made of steel, usually running from 12 in. to 48 in. in diameter and from 1/2 to 1 in. in thickness.

The cutting or abrasive disks are cemented to the face of the steel disk, clamped in a press until the cement is set, and then mounted on the spindle of the machine just as a grinding wheel would be. The grinding circles, as the abrasive disks are called, are covered with any abrasive desired, different materials giving best results on different work. These were originally made from sheets of emery or other abrasive cloth, having the grains all over the surface. The small particles of the material being ground clogged the grains of the abrasive and reduced the efficiency. Grooves were cut in the steel disk to form a sort of cushion under the circles and among the latest development is the spiral circle, in which the abrasive is deposited on the cloth base or foundation in the form of a spiral with a blank space between. This gives a continual shearing action as the grains of abrasives pass of the face by the work being ground and the spaces also serve as a clearance for the chips ground from the work. These cut faster than the older forms of circles and give remarkable results in many cases. Another form has the cutting surface divided into small squares or other shaped parts.

The speed varies from about 2200 to 3000 ft. per minute at the rim of the disks, according to the work to be ground. The power required varies with the work being done, its surface in contact with the grinding circle having a direct bearing on this point. With motor-driven machines a 12-in. disk machine is fitted with a 2 horse-power motor, an 18-in disk with 5, and a 23- or 26-in. disk with a 10 horse-power motor.

With a belt-driven machine the 12-in. has about a 5-in. pulley and a 3-in. belt, while for a 26-in. disk the spindle pulley is 7 in. in diameter for a 6-in. belt. With belt drive it is customary to figure on about half the power consumption as that indicated by the size of motor, which represents maximum requirements, the belt being average power required.

Where work is to be finished in this way the allowance for finishing need not be large, although large amounts can be ground off if necessary. On work that is machined first, from 0.005 in. to 0.050 in. is plenty for a good finish.

The main considerations are: Stock to be removed, distance to be traveled by grindings before escape, area of surface to be ground and the thickness of the adjacent stock for absorbing heat from the grinding and to prevent spring and distortion.

WORK DONE BY DISK GRINDERS

The following table from tests with Besley Helmet spiral disks on bars 1 in. square gives some idea of the possibilities and can be used as a general guide. These were all 24 grain and an 18-in. circle.

	Average time in seconds for grinding 1 cu. in. during life of circle
Yellow brass	25
Aluminum alloy	42
Phosphor bronze	60
Malleable iron	90
Cast iron	100
Cast crucible steel	444
Wrought mild steel	600

Another feature to be considered in disk grinding is to avoid rigid clamping as much as possible. This requires time and often makes the grinding time longer owing to more metal being removed where it is simply a case of cleaning up a surface. In cases of this kind it is better to let the work float against the disk so that all the high points come in contact first and reduce the total grinding to the simple taking down of the high points to just clean up the low spots.

Where work is small and can be ground all over the surface of the grinding circle, they can be worn out very evenly and economically, but on work which can only use the outer surface, grinding circles are made with an extra large hole and are more economical for this work.

Grinding circles glaze the same as grinding wheels and can be sharpened with a wheel dresser or a stiff wire brush. The brush, such as is used for cleaning castings, is particularly good when grinding carbon, brass, aluminum or cast iron.

Work should always be moved across the face of the grinding disk both on account of prolonging the life of the circle and for grinding a perfectly flat surface.

Most disk grinding machines are designed to use single belts, the pulleys being made wide enough to allow of this.

In grinding aluminum and copper there is a tendency for the abrasive material to come off the cloth backing sheet on which it is held. If this occurs it can be helped by filling the circle with paraffine, beeswax or machine oil before starting to grind.

FINISH GRINDING

For finishing brass for nickel plating or when a specially nice finish is wanted, the disks can be faced with leather disks about 3/16 in. thick and charged with fine abrasive, such as 120 or even finer, alundum, carborundum or other abrasive material.

Leather disks are also good for fine finish on any kind of work, as it can be made to very closely resemble handwork. An even closer resemblance to handwork can be had by using a felt disk, about 7/16 in. thick, and charged with very fine abrasive.

Generally speaking the "mile-a-minute" speed, about 5300 ft. per minute, is good for most disk grinding, while for brass finishing work, 6500 ft. per minute is good practice.

Summed up in tabular form this gives:

Diam. of disk	R. p. m. for removing stock	R. p. m. for brass and burring and finishing
12 in.	2,000	2,600
18 in.	1,400	1,800
20 in.	1,250	1,600
23 in.	1,100	1,300
26 in.	1,000	1,250

RECOMMENDED SPEEDS

Taking an 18-in. disk as an example, the recommended speed for cast iron is 1400, for general work such as machine steel 1650, and for brass work 1800 revolutions per minute. This corresponds to about 6650, 7840 and 8550 ft. per minute for rim speed of the disks.

Disk grinders are made double, *i.e.*, with two disks in the center of the machine, one stationary and the other on a sliding head, so that work can be held between them on a suitable rest and ground on both sides at once. This allows remarkably fast work to be done and many classes of work are finished in this way. A very large variety of work can be done in this way, some of the many examples given by the builders being cited below.

Special holding fixtures are made for many kinds of work; in the case of brass hexagon nuts, 42 nuts 5/8 in. outside diameter being held at one grinding. This decreases to four nuts at once with a diameter of 3 1/8 in.

BROKEN AND ROUGH SURFACES

Where the surface to be ground is broken as in pipe ends or pipe flanges, a larger area can be ground satisfactorily as the chips have less distance to travel after being cut off. As an example, cast-iron pump flanges 6 in. outside and 3 in. inside diameter can be ground at the rate of about 100 surfaces per hour. This means 2100 sq. in. of surface, the stock removed being about 1/16 in. This job was not entirely successful until a groove was turned in the center of

the flange surface to allow the grindings to get out of the way without traveling all the way across the face of the flange.

The disk grinder can be used successfully to grind from the rough stock if a few conditions are observed.

The work must be done as rapidly as possible to prevent heating the work and glazing the circle. This means that coarse grains give the best results if enough power is provided and the work can be forced against the disk with pressure enough to make it bite or cut.

TESTS OF A GRINDING DISK

In the *American Machinist*, Vol. XXXIV, 1908, p. 202, F. N. Gardner of the Gardner Machine Company gave some interesting tests of a new grinding disk. These disks are made by putting a heavy coating of abrasive on the cloth, and before it sets pressing a plate covered with square points into the plastic abrasive. This gives the disks a series of raised points which seem to add to their cutting qualities.

The disks are all the same quality, being made by the same man on the same machine with 16 grain, except Nos. 5 and 6. The first was a disk of No. 24 emery cloth and the last of the same abrasive on a paper backing. All were 20 in. in diameter.

Although the efficiency of the last two was low, it is interesting to note that the paper disk removed about five times as much metal as the disk with a cloth backing.

Disk number	Time used in minutes	Stock removed in cubic inches	Number of times dressed	Average cutting rate cubic inches per minute	Cutting rate first half of time used	Cutting rate second half of time used
1	754	349.85	0	.464	.442	.486
2	137	42.13	6	.307	.344	.270
3	540	113.95	0	.211	.238	.184
4	68	27.97	2	.411	.546	.276
5	71	2.41	4	.034	.062	.006
6	73	12.48	2	.171	.273	.069

TABLE 7.—RESULTS OF TESTS TO SHOW THE EFFICIENCY OF ABRASIVE DISKS

MACHINES USING ABRASIVE BELTS

Until the advent of the disk grinder we never dreamed of the amount of work that could be performed with a sheet of emery cloth when properly supported and driven at a high rate of speed, but had always considered it as a very convenient form in which to have an abrasive material for finishing work and getting into corners. The disk grinder changed our ideas in that respect

and now comes another development, which, though it can be likened to the other machines in some ways, uses emery cloth in the form of endless belts and performs almost marvelous feats of grinding. Its work is not confined to any class but includes castings, forgings or almost anything that can be finished by grinding, from making drop forgings into any required shape to finishing

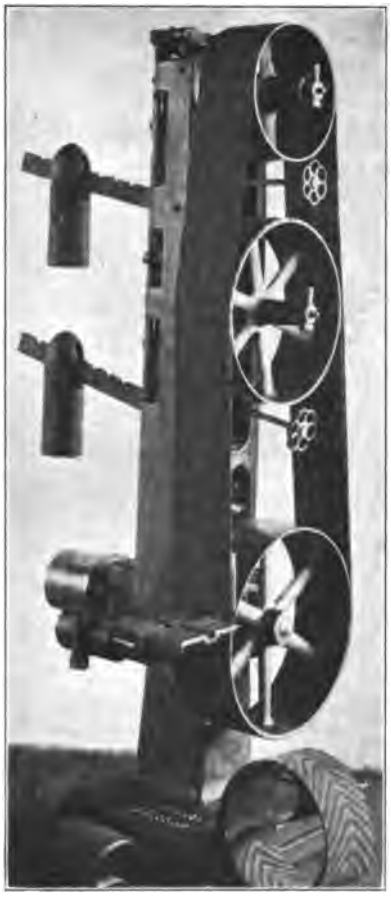


FIG. 88. THE BLEVNEY EMERY BELT GRINDER.

knife handles of wood, horn or rubber and grinding both the handle and the metal mountings at the same time.

One of the plain machines is shown in Fig. 88 and consists of a stand or column, three pulleys mounted thereon as the patent sharp would say and two belts, one of leather and the other of emery cloth. The leather belt is the shorter and inside the other, which runs around the top and bottom pulleys and is driven by contact with the leather belt along the front side and around the bottom.

There are several reasons for this arrangement of belts. It allows both to be tightened to the desired tension independent of the other; it gives the emery belt an opportunity to cool off after the heat due to contact with the work; it allows any desired cushion to be obtained behind the grinding belt and the cost is less for the leather belt than as though it was made the full length.

The tension on the belts is kept uniform by the weights at the back and it is also possible to give either of the upper pulley shafts a slight inclination to offset any tendency of the belt to run to one side. The belts run past a support seen behind the belt and just above the table so that by pressing any piece of work against the belt at that point a flat surface is produced without any skill on the operator's part. Where this is to be square or at a given angle with another surface it is placed on the table or in any sort of fixture desired. Regular buffing can be done by removing the table and using the curved part of the belt just below the supporting plate and this has the advantage over most buffing wheels of having the emery surface thoroughly cushioned.

CUSHIONING THE GRINDING BELT

It will be noticed that the leather belt has ridges across its face as can be seen at the top of the middle pulley. These are to give what might be called grinding points and cushions between to allow room for the chips to get out of the way without rolling over and over and scratching the work before they escape, which is one reason for the grooves in a disk grinder. While this belt is best for fibrous material where large chips are had, a perforated or relieved belt is better for metal. This has large countersunk holes in the outside. These perforations and depressions are staggered so that all portions of the width of the belt are alternately supported by the solid leather and then cushioned. The difference in the length of the belts force the portions coming together to change position each revolution so that every part of the surface receives equal and maximum wear, getting all the work possible out of the belt.

Steel belts, perforated in a similar manner to the leather belting, are also used for work which does not require the cushioning to the same extent as that afforded by the leather.

The belting is made up from rolls of abrasive cloth which can be bought from any large dealer and cut into the desired lengths and widths. The abrasive is cleaned from one end for a lap and a joint made with glue in the ordinary way so that the cost of the abrasive material is low and the waste is very little, while the entire surface is used up in doing work.

The first thought is that a belt of cloth will be torn by a rough point on a casting or forging, and regular grinders and buffers have been hired to see if this would be the case. But they have never been able to get a hole in a belt until it wore down from constant use; then the hole would be worn and not torn. The whole secret of the matter is that it is practically impossible to get the work

against the belt hard enough to do any damage before the sharp corner has been ground away as the belt travels 7000 ft. a minute.

The idea of running an abrasive belt over a support and grinding flat work by pressing against it is not new, as that plan is being used to polish the heads on cap-screws and bolts, but the use of the leather belt and the perforations to still farther add to the cushioning effect is a later development. That the cushioning is of real benefit is shown by the grinding of such materials as hard rubber or the softer metals which clog an emery wheel and usually glaze the materials, while with this method the grinding seems to be about as clean as with iron or steel.

In addition to plain surface grinding, such as the bottom of flatirons, the sides of sledge hammers and similar work, the machine has been adapted to many other forms of work, many of them being done automatically such as the curved face of the claw of a carpenter's hammer without any guiding on the part of the operator.

The hammer-head is held in a fixture shown at the left on the base, one being inserted while the other is being ground, and when the grinding is finished the operator merely pulls out one fixture and slips the next one into place while he changes the hammer-heads. Every hammer is exactly alike, and the grinding is done in a very short time.

CHAPTER VI

GRINDING WHEELS

Grinding wheels are made by three processes, vitrified, silicate (or semi-vitrified) and elastic. The surfaces of the three classes of wheels are shown in Fig. 89.

Wheels are manufactured in a great number of shapes and sizes, to suit all classes of grinding machinery. Among the commercial abrasives of which they are composed are emery, corundum, carborundum, alundum, crystolon, carbolite and carbonite. They vary in hardness, though it does not follow that the hardest grit is the best for cutting purposes; the shape and form of fracture of the particles must also be taken into consideration. We may imagine a wheel made up from diamonds, the hardest substance in nature, and whose individual kernels were of spherical form; it is quite obvious that it would be of little service as a cutting agent. On the other hand, if these kernels were crystalline or conchoidal in form it would probably be the ideal grinding wheel.

Emery is a form of corundum found with a variable percentage of impurity; it is of a tough consistency and breaks with a conchoidal feature.

Corundum is an oxide of aluminum of a somewhat variable purity according to the neighborhood in which it is mined; its fracture is conchoidal and generally crystalline.

Carborundum is the name given to carbide of silicon as manufactured in the electric furnace by the Carborundum Company. The principal materials entering into its manufacture are coke, which supplies the element carbon; and sand, supplying the silicon. The mass of coke and sand is raised to a very high temperature which destroys all substances in the coke and sand except the carbon and silicon, the atoms of these two elements then uniting as carborundum, a product that breaks with a sharp, crystalline fracture.

The grade table of the Carborundum Company will be found on page 119. This table gives grit numbers and grade letters for carborundum wheels as recommended by the makers for all classes of grinding operations.

Alundum is an artificial product, being a fused oxide of alumina. It is of uniform quality, of about 98 per cent. of purity. It breaks with a sharp, conchoidal fracture and has the toughness of emery.

The mineral, bauxite, from which alundum is made by fusing in the electric furnace, derives its name from the ruined city and castle of Les Baux, in the southern part of France where it was originally discovered. It is now obtained

in higher degree of purity in the United States. The alundum process has been perfected and commercially applied by the Norton Company for their grinding wheels.

Crystolon, which is also used by the Norton Company in the manufacture of wheels is, carbide of silicon, and is one of the most recent abrasive materials put into commercial use. Like alundum, crystolon is an electric furnace

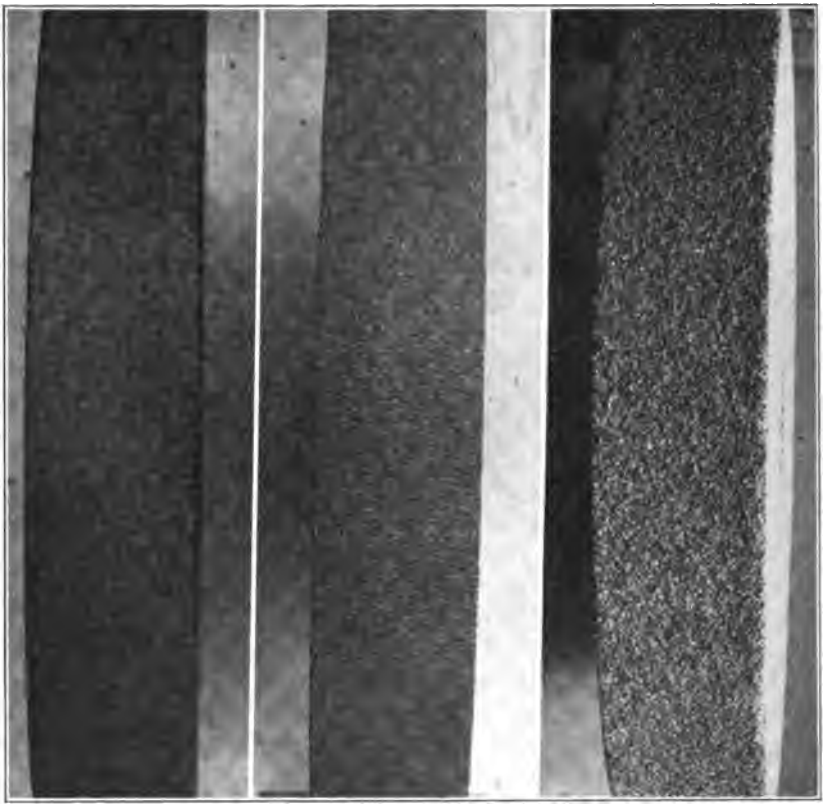


FIG. 89. SHOWING TEXTURE OF WHEELS.—*Norton.*

product. Its characteristic property of brittleness makes it efficient for polishing and grinding such metals as cast iron, chilled iron, brass, also marble, granite and pearl, in fact such materials in general as possess a low tensile strength.

The tables for selections of grades beginning on page 117 shows clearly the different classes of work for which the abrasives, crystolon and alundum, are respectively recommended.

Aloxite is an aluminum oxide, fused in an electric furnace and one of the later products of the Carborundum Company.

Carbolite (carbide of silicon) is an electrical abrasive forming one of the materials used in the products of the American Emery Wheel Works. Carbolite wheels are recommended by the makers for grinding the softer metals, especially cast iron and brass, and also for grinding such materials as rubber, leather, pearl, etc.

Carbondite is another artificial abrasive made in the electric furnace. It is one of the materials used in the wheels of the Safety Emery Wheel Company.

THE WHEEL-MAKING PROCESSES

The making of vitrified wheels may be briefly described as follows:

In the manufacture of vitrified wheels no pressing or tamping is employed. The abrasive or cutting material, together with such materials as form the bond, are placed in power mixing kettles with sufficient water to form a plastic mass.

When properly mixed, it is drawn off into forming rings of the required sizes and placed in dry rooms. After drying some time the rings can be removed and the crude wheels handled. They are then reduced to the approximate sizes of the finished wheels on shaving machines, and again placed in dry rooms where they remain until thoroughly dried out.

In large ovens or kilns they are subjected to high temperature—nearly 3000° F.—which causes the "bond" that holds together the abrasive grains, or cutting particles, to fuse and vitrify. The time required is from 6 to 20 days —depending on the size of kiln.

From the kilns the wheels go to the truing department where they are reduced to size, faced, and made to run perfectly true. They are now ready for the grading room. The wheels are then tested and inspected.

The vitrified process produces open texture, free-cutting wheels. They are not affected by weather, time, water, oils, acids or soda, and are used for both wet and dry grinding.

Silicate wheels are made by the tamping process. Machinery is employed in mixing the bond with abrasive and alundum. While in a plastic state it is tamped in iron molds.

The wheels are then placed in drying ovens where they are left for a short period. They are now ready for the truing room, and are treated from this point on the same as vitrified wheels.

Wheels are made of larger diameter and greater thickness by the silicate process than by other methods. They are made either with or without the wire web shown in Fig. 90. Some makers recommend the web where severe service is required. Others do not believe it is essential. These wheels are water-proof and are, therefore, equally serviceable for wet and dry grinding.

Wheels made by the elastic process are the only wheels that can be made very thin and at the same time have the necessary strength and elasticity to

make them durable. Elastic wheels are bonded by gums such as rubber, shellac and resins; the mixture of bond and abrasives being heated and pressed in molds. Wheels are made by this process as thin as 1/32 in. up to 4 in. diameter; 1/16 in. thick up to 10 in. diameter; 1/8 in. thick up to 12 in. diameter. Very fine wheels of small diameter have been made as thin as 1/64 in. A table of minimum thicknesses of elastic wheels is given on page 111.

They are used chiefly for saw gumming, grinding between the teeth of gears, sharpening molding cutters and wood-working tools, cutting off small stock,

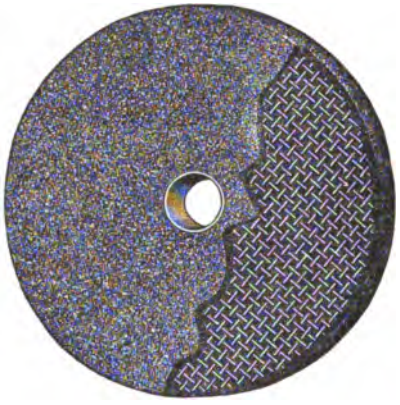


FIG. 90. GRINDING WHEEL WITH WIRE WEB.

thin strips, tubing and wire, and for slotting and roll grinding. They may be run in water, caustic soda or dry.

Wheels are also made by this process in cylinder and cup shapes for chisel grinding, cutlery grinding, etc., by automatic machinery.

In testing the different classes of wheels they are run on a testing machine at a peripheral speed of at least 9000 ft. per minute, giving a stress of 250 lb. per square inch.[1] When run at the usual periphery speeds the stresses are: At 4000 ft., 43 lb. per square inch; 5000 ft., 75 lb.; 6000 ft., 108 lb. per square inch.

[1] During some recent experimental testing in the Norton Company plant with a few 12 × 1 1/2 in. wheels of No. 46 grain and various grades of hardness, taken from stock at random, it was found that grade "J" and harder failed to break when running 5 minutes at 6200 r. p. m., or a surface speed of 19,500 ft. per minute. A faster speed could not be obtained on the testing machine being used; therefore, the breaking speed could not be ascertained.

The tensile strength of a wheel increases with increased hardness and fineness of grain. A 46-J wheel is a very soft grade and the grain is comparatively coarse—about theweakest wheels of this size used in ordinary practice. This particular test gave a factor of safety of 13.4, which shows the grinding wheel, as made by modern scientific methods of manufacture, to be far in advance of the wheels made in past years in point of safety.

The normal speed at which wheels of this character are usually run in practice, is about 5000 to 6000 surface feet per minute.

Thus the wheel under test is run at a speed from 50 to 100 per cent. higher than that at which it will be operated in practice and is subjected to stresses two or three times as high as imposed by the usual operating speeds. If a wheel is defective it will break under this test.

MINIMUM THICKNESS OF WHEELS

Tables 7, 8 and 9, from "Grits and Grinds," published by the Norton Company, show minimum thicknesses of wheels made by the different processes. A wheel of fine grit can be made thinner than a wheel of coarse grit, and have the same factor of safety. The minimum thickness depends upon both the diameter and the coarseness of the grit used.

For example, a 24-in. vitrified wheel of No. 10 or No. 12 grain should not be made thinner than 2 in., while if a grain No. 36 or finer is used it is considered a safe wheel at 1 in. thick.

	Grain				
	14 and 16	20 and 24	30 and 36	46 and 60	70 and finer
Diameter in inches	Minimum thickness of wheels in inches				
28–30	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
24–26	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
20–22	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
16–18	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
14–15	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$
10–12	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
7–9	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
5–6	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{32}$
3–4	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{32}$
1–2	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$

TABLE 7.—MINIMUM THICKNESS OF ELASTIC WHEELS

	Grain							
	10 and 12	14 and 16	20 and 24	30	36	46	50 to 120	150 and finer
Diameter in inches	Minimum thickness of wheel in inches							
32 to 36	2½	2½	2	2	2	2	2	2
24 to 30	2	2	1½	1¼	1	1	1	1
20 to 22	1½	1½	1¼	1¼	1	¾	¾	¾
16 to 18	1½	1½	1	1	¾	¾	½	½
14 to 15	1¼	1¼	¾	¾	¾	½	⅜	⅜
10 to 12	1¼	1¼	⅝	⅝	½	⅜	⅜	¼
7 to 9	1	1	¾	⅜	5/16	¼	¼	¼
5 to 6	1	1	¾	⅜	¼	¼	¼	3/16
3 to 4	.....	1	¾	⅜	¼	3/16	⅛	⅛
1 to 2	.....	.....	¾	.....	¼	⅛	⅛	⅛
Smaller than 1 in.	.....	.....	.....	.....	.....	.....	1/16	1/16

TABLE 8.—MINIMUM THICKNESS OF VITRIFIED WHEELS

Diameter in inches	Grain: 10, 12, 14, and 6 — Wire web: With	Grain: 10, 12, 14, and 6 — Wire web: Without	Grain: 20 and 24 — Wire web: With	Grain: 20 and 24 — Wire web: Without	Grain: 30 — Wire web: With	Grain: 30 — Wire web: Without	Grain: 36 — Wire web: With	Grain: 36 — Wire web: Without	Grain: 40 and 50 — Wire web: With	Grain: 40 and 50 — Wire web: Without	Grain: 60 to 120 — Wire web: Without	Grain: 150 and finer — Wire web: Without
	Minimum thickness of wheel in inches											
44 to 48	3	3	2	3	2	3	2	3	2	2	2	
38 to 42	2½	2½	2	2½	2	2½	2	2½	2	2	2	
32 to 36	2½	2½	2	2½	1½	2½	1½	2½	1½	1½	1½	
28 to 30	2	2	2	2	1	2	1	2	1	1	1	
24 to 26	2	1½	1½	2	1	2	1	2	1	1	1	
20 to 22	1⅞	1½	1½	1½	1	1½	1	1½	1	1	1	
16 to 18	1½	1	1	1	⅞	1	⅞	1	⅞	⅞	⅞	
14 to 15	1½	1	1	1	⅞	1	⅞	1	⅞	⅞	⅞	
10 to 12	1¼	⅞	⅞	⅞	½	⅞	½	⅞	⅞	⅞	⅞	
7 to 9	.....	⅞	⅞	⅞	½	¾	½	⅞	⅞	⅞	⅞	
5 to 6	.....	.....	.....	.....	½	.....	½	.....	½	½	½	
3 to 4	.....	.....	.....	.....	½	.....	½	.....	½	½	½	
1 to 2	.....	.....	.....	.....	½	.....	½	.....	7/16	½	½	

TABLE 9.—MINIMUM THICKNESS OF SILICATE WHEELS

It will be noted by the above table that it is not practical to make a wheel with wire-web as thin as without wire-web. This may seem strange to some, in view of the fact that the use of the wire-web is supposed to strengthen thin wheels. Under a certain thickness however, the wire-web tends to weaken rather than strengthen the wheel, because in tamping a very thin wheel, there is not enough of the abrasive and bond to hold the wire in its correct position while tamping. The result is that a separation of material is apt to be caused.

It is stated in *Grits and Grinds*, that the silicate process of manufacturing grinding wheels does not permit of the same range of grades as the vitrified process. In the accompanying table it will be noted that silicate wheels are not made softer than grade "H," and that larger wheels than 24 in. diameter should not be made softer than "I." From 30 in. up to 48 in. diameter the grade should not be softer than "J." The limit of hardness depends upon

the diameter and the size of the grain used. For example: A 48-in. wheel 80 and finer can be made only as hard as "O" while wheels of 6 in. diameter and smaller of the same grain can be made as hard as "R."

Dia. in inches	Grain								
	All can be made as soft as grade	14	16	20 and 24	30	36	46 and 50	60 and 70	80 and finer
		Can be made as hard as grade							
48	J	S or T	R or S	Q or R	Q or R	Q	O or P	O	O
42	J	S or T	R or S	Q or R	Q or R	Q	O or P	O	O
36	J	S or T	R or S	Q or R	Q or R	Q	O or P	O	O
30	I	S or T	R or S	Q or R	Q or R	Q	O or P	O	O
28	I	S or T	R or S	Q or R	Q or R	Q	P	O	O
26	I	S or T	R or S	Q or R	Q or R	Q	P	O	O
24	H	S or T	R or S	Q or R	Q or R	R	Q	P or Q	O or P
22	H	S or T	R or S	Q or R	Q or R	R	Q	P or Q	O or P
20	H	S or T	R or S	Q or R	Q or R	R	Q	P or Q	O or P
18	H	S or T	R or S	Q or R	Q or R	R	Q	P or Q	O or P
16	H	S or T	R or S	Q or R	Q or R	R	Q	P or Q	O or P
14	H	S or T	R or S	Q or R	Q or R	R	Q	P or Q	O or P
12	H	T	T	T	S	S	R or S	Q or R	Q
10	H	T	T	T	S	S	R or S	Q or R	Q
9	H	T	T	T	S	S	R or S	Q or R	Q
8	H	T	T	T	S	S	R or S	Q or R	Q
7	H	T	T	T	S	S	R or S	Q or R	Q
6 and smaller	H	T	T	T	S	S	S	R or S	R

TABLE 10.—LIMITS OF HARDNESS OF SICILATE WHEELS

Usually grinding wheel breakages are due to insufficient care in mounting and using the wheel; the most common causes of accident being the catching of work between the wheel and the rest; mounting wheels between small flanges or between flanges that bear unevenly when the nut is tightened; not using any flanges but simply screwing a nut against the wheel; allowing the arbor to

become loose in the boxes from wear; allowing the wheel to get out of true and out of balance; heating and expansion of the arbor; forcing the wheel on the arbor; using shaky machines and subjecting the wheels to extreme side pressure.

Further reference to these sources of accident and to methods of safeguarding wheel operation in the shop will be made at another point.

THE GRADING OF WHEELS

A grinding wheel is made up of two kinds of material, the "grit" or cutting material, and the bond. The cutting efficiency of a wheel depends largely on the grit; the grade of hardness depends principally on the bonding material used. The efficiency in grinding a given metal is dependent largely upon the "temper," or resistance to fracture, and character of fracture of the grit or cutting grains of the wheel.

Some interesting particulars of the various bonding materials are given by George N. Jeppson:

"The function of the bond is not only to hold the cutting particles of the wheel together and to give the wheel the proper factor of safety at the speed it is to be run, but it must also be possible to vary its tensile strength to fit the work it is called upon to do. We often hear the operator say that the wheel is too hard or too soft. He means that the bond retains the cutting teeth so long that they become dulled, and this wheel is inefficient; or, in the case of a soft wheel, the bond has not been strong enough to hold the cutting teeth and they are pulled out of the wheel before they have done the work expected.

"The bond to be used for a given operation depends on the wheel and work speeds, area of wheel in contact with the work, vibration in wheel spindle or work, shape and weight of work, and many other like variables.

"Wheels are bonded by what are known as the vitrified, silicate, elastic and rubber processes. No one bond makes a superior wheel for all purposes; each one has its field.

"**The vitrified bond** is made of fused clays, is unchanged by heat or cold, and can be made in a greater range of hardness than any other bond. It does not completely fill the voids between the grains, and therefore, a wheel bonded in this way having more clearance than any other, is adaptable for all kinds of grinding except where the wheel is not thick enough to withstand side pressure. This bond has no elasticity.

"**The silicate bond** is composed of clays fluxed by silicate of soda at low temperatures. It is not as stable as the vitrified bond as regards dampness, gives less clearance between grains, and has a range of hardness below that of the vitrified in the harder grades. This bond has no elasticity and will not make a safe wheel of extreme thinness.

"**The elastic bond** is composed of shellac and other gums. It completely fills the voids of the wheel, has a limited range of grades, has a high tensile strength and elasticity, and can be used for the making of very thin wheels. The rubber or vulcanite bond has the general characteristics of the elastic, but its grades of hardness cannot be varied to the same extent and its uses are limited."

GRAIN AND GRADE

Grinding wheels are made in various combinations of coarseness and hardness to meet the variety of conditions under which they are used. The cutting material is crushed and graded from coarse to fine in many sizes desig-

nated by number. Thus the sizes of grain used in the Norton wheels are numbered 10, 12, 14, 16, 20, 24, 30, 36, 46, 50, 60, 70, 80, 90, 100, 120, 150, 180, 200. Finer grades known as flour are also used, sometimes these being designated as F, FF, FFF, etc. By No. 20 grain is meant a size that will pass through a grading sieve having 20 meshes to the linear inch.

The term "grade" refers to the degree of hardness of the wheel or the resistance of the cutting particles under grinding pressure. A wheel from which the cutting particles are easily broken, causing it to wear rapidly, is called soft, while one which retains its particles longer is called hard. Wheels are usually graded from soft to hard, although in some instances the process is reversed.

Manufacturers of grinding wheels have different grade lists as follows:

The following grade list is used to designate the degree of hardness of vitrified and silicate wheels, both alundum and crystolon.

E.....Soft
F
G
H
I.....Medium soft
J
K
L
MEDIUM.....M.....MEDIUM
N
O
P
Medium hard.....Q
R
S
T
Hard.....U
V
W
X
Extremely hard.....Y
Z

TABLE 11.—NORTON COMPANY'S GRADE LIST

The intermediate letters between those designated as soft, medium soft, etc., indicate so many degrees harder or softer; *e.g.*, L is one grade or degree softer than medium; O, two degrees harder than medium, but not quite medium hard.

Elastic wheels are graded as follows: 1, 1 1/2, 2, 2 1/2, 3, 4, 5 and 6. Grade 1 is the softest and grade 6, the hardest.

Class of work	Alundum		Crystolon	
	Grain	Grade	Grain	Grade
Aluminum castings	36 to 46	3 to 4 Elas.	20 to 24	P to R
Brass or bronze castings (large)			20 to 24	Q to R
Brass or bronze castings (small)			24 to 36	P to R
Brick, fire			16 to 20	P to Q
Brick, pressed			16 to 20	O to P
Car wheels, cast iron			16 to 24	P to R
Car wheels, chilled	20	Q	16 to 24	O to Q
Cast iron, cylindrical	24 comb.	J to K	30 to 46	J to L
Cast iron, surfacing	20 to 46	H to K	16 to 30	J to L
Cast iron (small) castings	24 to 30	P to R	20 to 30	Q to S
Cast iron (large) castings	16 to 20	Q to R	16 to 24	Q to S
Chilled iron castings	20 to 30	P to U	20 to 30	Q
Dies, chilled iron			20 to 30	O to Q
Dies, steel	36 to 60	J to L		
Drop forgings	20 to 30	P to R		
Hammers, cast steel	30	P		
Hollowware, inside grinding			30	Q
Hollowware, thin edges			24	U
Internal grinding of automobile cylinders (cast iron)			30 to 60	I to L
Internal grinding, hardened steel	46 to 60	J to M		
Knives (paper), automatic grinding	36 to 46	J to K		
Knives (planer)	30 to 46	J to K		
Knives, leather shaving	60	N to O		
Knives, leather splitting	24 to 30	1 to 2 Elas.		
Knives, moulding bits, etc	46 to 60	3 Elas.		
	46 to 60	M		
Knives (planing mill), hand grinding	46 to 60	J to M		
Knives, shear and shear blades	30 to 60	J to M		
Knives, shoe	60	M		
Lathe centers	46 to 120	J to M		
Lathe and planer tools	20 to 24	P Sil.		
	20 to 36	O to P		
Machine shop use, general	20 to 36	O to Q		
Malleable iron castings (large)	14 to 20	P to U	16 to 20	R to S
Malleable iron castings (small)	20 to 30	P to R	20 to 30	Q to S
Marble, finishing			150 to F	M
Marble, roughing			16 to 46	M
Marble, coping			36 to 46	O to S
Marble, moulding			4	O
Milling cutters, automatic or semi-automatic grinding	46 to 60	H to M		
Milling cutters, hand grinding	46 to 60	J to M		

NORTON COMPANY'S TABLE FOR SELECTION OF GRAIN AND GRADE OF ALUNDUM AND CRYSTOLON WHEELS

TABLE 12.—SELECTION OF GRADE

Class of work	Alundum		Crystolon	
	Grain	Grade	Grain	Grade
Nickel castings	20 to 24	P to Q	20 to 24	R
Pearl grinding, roughing			30 to 50	P to U
Pearl grinding, finishing			100 to 150	M to P
Plow bodies (cast iron), surfacing			24	R
Plows (steel), jointing	20 to 24	R to S		
Plow points (chilled iron), surfacing			20 to 30	Q to S
Plows (steel), surfacing	16 to 24	Q to S		
Porcelain, roughing			36 to 50	O to R
Pulleys, (c. i.) surfacing faces of			30 to 36	K to L
Radiators (cast iron), edges of			24 to 30	R to S
Razors, grinding and concaving	46 to 120	H to O		
Reamers, taps, milling cutters etc., hand grinding.	46 to 60	K to O		
Reamers, taps, milling cutters, etc., special machines.	46 to 60	J to M		
Rolls (cast iron), wet	24 to 36	J to M	24 to 36	J to M
Rolls (chilled iron), finishing	70	1½ to 2 Elas.	70 to 80	1½ to 2 Elas.
Rolls (chilled iron), roughing			30 to 46	2 to 3 Elas.
Rubber	30 to 50	J to K	30 to 50	K to M
Sad irons, finishings			80 to 120	Q to R
Sad irons, roughing			20 to 30	Q to S
Saws, gumming and sharpening	36 to 50	M to N		
Saws, cold cutting-off	60	O to Q		
Shovels, edging	24	Q		
Spiral springs, ends of	16 to 20	Q to R		
Steel (soft), cylindrical grinding	24 comb.	L to N		
	46 to 60	L to N		
Steel (soft), surface grinding	24 to 36	H to K		
Steel (hardened), cylindrical grinding	24 comb.	K		
	46 to 60	J to L		
Steel (hardened), surface grinding	36 to 46	H to K		
Steel, large castings	12 to 20	Q to U		
Steel, small castings	20 to 30	P to R		
Steel (manganese), safe work	16 to 46	L to P		
Steel (manganese), frogs and switches	14 to 16	Q to U		
Structural steel	16 to 24	P to R		
Stove castings	20 to 36	P to Q	20 to 36	Q to R
Twist drills, hand grinding	46 to 60	M		
Twist drills, special machines	36 to 60	K to M		
Wagon springs, ends of	20 to 30	P to R		
Wire, ends of steel	36 to 80	Q to R		
Wrought iron	12 to 30	P to U		
Woodworking tools	46 to 60	K to M		

NORTON COMPANY'S TABLE FOR SELECTION OF GRAIN AND GRADE OF ALUNDUM AND CRYSTOLON WHEELS

TABLE 12.—SELECTION OF GRADE.—(*Continued*)

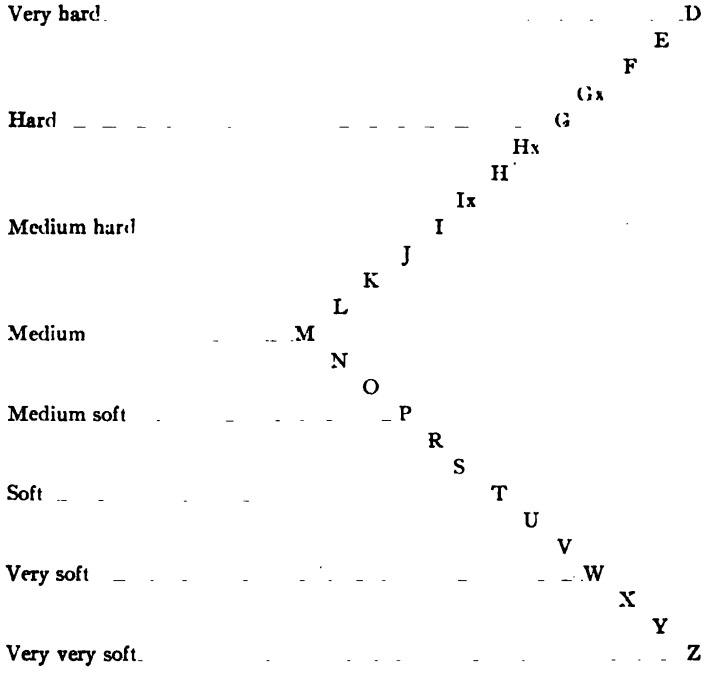


TABLE 13.—THE CARBORUNDUM COMPANY'S GRADE LIST

Work	Grit numbers	Grade letters
Aluminum castings	16 to 24	H to I
Brass castings (large)	16 to 24	G+ to H
Brass castings (small)	24 to 36	H to I
Bronze castings	20 to 30	H to I
Brick, fire	14 to 16	H to I
Brick, pressed	14 to 16	I to J
Car wheels	14 to 24	G+ to I+
Dies (surfacing hardened steel)	30 to 36	J to K
Dies (chilled iron)	24 to 30	H to I+
Drop forgings (general)	20 to 36	G+ to H+
Files (edging)	24 to 30	D to E
Glass (rough edge grinding)	100 to 120	I to K

TABLE 14.—CARBORUNDUM COMPANY'S SELECTION OF GRAIN AND GRADE

make them durable. Elastic wheels are bonded by gums such as rubber, shellac and resins; the mixture of bond and abrasives being heated and pressed in molds. Wheels are made by this process as thin as 1/32 in. up to 4 in. diameter; 1/16 in. thick up to 10 in. diameter; 1/8 in. thick up to 12 in. diameter. Very fine wheels of small diameter have been made as thin as 1/64 in. A table of minimum thicknesses of elastic wheels is given on page 111.

They are used chiefly for saw gumming, grinding between the teeth of gears, sharpening molding cutters and wood-working tools, cutting off small stock,

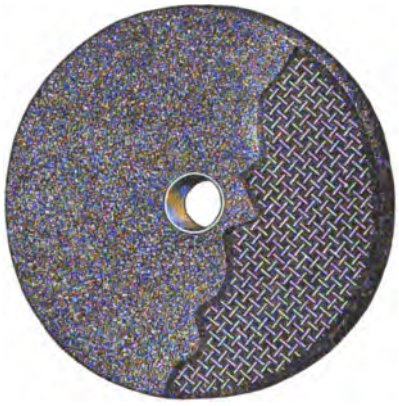


FIG. 90. GRINDING WHEEL WITH WIRE WEB.

thin strips, tubing and wire, and for slotting and roll grinding. They may be run in water, caustic soda or dry.

Wheels are also made by this process in cylinder and cup shapes for chisel grinding, cutlery grinding, etc., by automatic machinery.

In testing the different classes of wheels they are run on a testing machine at a peripheral speed of at least 9000 ft. per minute, giving a stress of 250 lb. per square inch.[1] When run at the usual periphery speeds the stresses are: At 4000 ft., 43 lb. per square inch; 5000 ft., 75 lb.; 6000 ft., 108 lb. per square inch.

[1] During some recent experimental testing in the Norton Company plant with a few 12 × 1 1/2 in. wheels of No. 46 grain and various grades of hardness, taken from stock at random, it was found that grade "J" and harder failed to break when running 5 minutes at 6200 r. p. m., or a surface speed of 19,500 ft. per minute. A faster speed could not be obtained on the testing machine being used; therefore, the breaking speed could not be ascertained.

The tensile strength of a wheel increases with increased hardness and fineness of grain. A 46-J wheel is a very soft grade and the grain is comparatively coarse—about theweakest wheels of this size used in ordinary practice. This particular test gave a factor of safety of 13.4, which shows the grinding wheel, as made by modern scientific methods of manufacture, to be far in advance of the wheels made in past years in point of safety.

The normal speed at which wheels of this character are usually run in practice, is about 5000 to 6000 surface feet per minute.

Thus the wheel under test is run at a speed from 50 to 100 per cent. higher than that at which it will be operated in practice and is subjected to stresses two or three times as high as imposed by the usual operating speeds. If a wheel is defective it will break under this test.

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For example, a 24-in. vitrified wheel of No. 10 or No. 12 grain should not be made thinner than 2 in., while if a grain No. 36 or finer is used it is considered a safe wheel at 1 in. thick.

	Grain				
	14 and 16	20 and 24	30 and 36	46 and 60	70 and finer
Diameter in inches	Minimum thickness of wheels in inches				
28–30	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
24–26	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
20–22	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
16–18	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
14–15	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$
10–12	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
7–9	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
5–6	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{32}$
3–4	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{32}$
1–2	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$

TABLE 7.—MINIMUM THICKNESS OF ELASTIC WHEELS

Grade	Classification	Style of work
I	Medium hard.....	Malleable and gray iron and similar work.
I¼		
I½		
I¾		
O	Hard.....	Soft steel castings. Surfacing plow shares.
O¼		
O½		
O¾		
N	Very hard.....	Very heavy steel castings ground with swing frame grinders and similar work.
N¼		
N½		
N¾		
E	Extra hard.....	Used on work where great durability is required.
E¼		
E½		
E¾		
D	Special extra hard...	Hardest wheel made for special work.

TABLE 15.—SAFETY EMERY WHEEL COMPANY'S GRADE LIST. VITRIFIED WHEELS—*Continued*

Grade No.	Classification	Style of work
1	Extra hard.....	Very hard work.
1½	Very hard.....	Edging fins, etc.
2		Chilled plow work.
2½	Hard.....	Hard gray iron cas.ings.
3	Medium hard.....	Light gray iron or malleable castings.
3½	Medium.....	Heavy tools, general machine shop work.
4	Medium soft.....	Brass castings.
4½	Soft.....	Moulding cutters.
5	Very soft.....	Saw gumming.
5½		
6	Extra soft.....	Surface work.
6½	Especially soft.....	Automatic knife grinding.
7		
7½	Special.	
8		

TABLE 16.—SILICATE WHEELS

Class of work	Number of grain	Grade
Coarse grinding		
Stove castings	20 to 30	I¾ to O½
Agricultural castings (malleable and gray iron)	16 to 20	I¾ to O½
Small malleable castings	24 to 36	I to O
Drop forging fins	20 to 30	O to N
Scale from soft steel forging	20 to 30	O to O½
Rough brass castings	16 to 24	I to O
Roughing out large machine-shop tools	20 to 30	I to O
Rough surfacing on wrought iron	16 to 24	I½ to O
Surfacing soft steel (coarse)	20 to 30	I½ to O½
Surfacing cast iron (coarse)	16 to 30	I to O
Surfacing chilled iron (coarse)	20 to 30	I½ to O½
Edging shovels	20 to 30	O to O¾
Steel plow joining	20 to 24	I½ to O
Jointing and edging agricultural implements	20 to 30	I to I¾
Thin edges of hollow-ware	20 to 30	N to N½
Chilled car-wheel grinding	16 to 20	I½ to I¾
Cast iron car-wheel grinding	16 to 24	I½ to I¾
Grinding car-wheel tires (steel)	20 to 30	I½ to I¾
Edges of wrought-iron butts and hinges	20 to 30	O to O½
Rough grinding on malleable car couplings	14 to 20	O½ to N
Grinding edges of cast-iron radiators	20	O to O½
Rough surfacing on sad irons	20 to 30	I½ to O
Grinding ends of iron or steel rods	20 to 30	O½ to E
Jointing wrought-iron bridge work	16 to 20	O½ to O¾
Surfacing cast-iron mould boards	20 to 36	I½ to O
Bronze casting	20 to 30	O to O½
Rough machine shop use	20 to 30	I½ to O½
Edging sheet steel	16 to 36	I¾ to O½
Wrought-iron wagon work	20 to 36	O½ to O¾
Grinding ends of carriage axles	20 to 36	O to O¾
Internal grinding (roughing out)	24 to 46	I½ to O½
Surface work on dies	20 to 46	M½ to I
Surface work on carriage axles	20 to 36	I¾ to O
Safe work	16 to 20	P½ to O
Edging sad irons	20	O to O½
Medium grinding and coarse tool work		
Saddlery hardware castings (malleable)	24 to 36	N or E
Surface brass (coarse)	30 to 36	P to P½

TABLE 17.—SAFETY EMERY WHEEL COMPANY'S TABLE FOR SELECTION OF GRAIN AND GRADE

Class of work	Number of grain	Grade
Medium grinding and coarse tool work—con.		
Surface tempered steel (coarse)	36 to 46	M to P
Grinding cast-steel hammers	30 to 36	I½ to I¾
Jointing edges of sheet-iron or steel	20 to 36	I½ to O½
Surfacing chilled-iron plows	20 to 30	I½ to O½
Stove mounting	24 to 36	O½ to N
Polishing edges of stoves	36 to 46	O to O½
Sharpening lawn mowers	36 to 60	P to I½
Pointing and sharpening guards	24 to 36	O to O½
Sharpening mower and reaper knives	46 to 60	I to I½
Water tool grinding	30 to 46	P to I
Twist drill grinding	46 to 60	M½ to P
General machine-shop use	20 to 36	I to I½
Shaping Mushett on high-speed tools, steel tools	24 to 36	P to I
Sharpening large machine-shop tools	24 to 36	P to I½
Finishing the heads of machine screws and bolts	36 to 46	P½ to I
Gumming and sharpening saws	46 to 60	A½ to M½
Planing-mill tools, moulding cutters, etc	46 to 60	M to M½
Planing-mill and paper-cutting knives	36 to 60	A to A½
Lathe and Planer tools	24 to 46	P to I
Edging files	30 to 60	O to N½
Ends of wagon springs	30 to 46	O to O½
Surfacing faces of pulleys	30 to 36	I to I½
Grinding out boiler holes in stove tops and centers	30 to 46	O¾ to N½
Small malleable or gray-iron castings	24 to 36	I½ to O
Bottoms and edges of iron shoe lasts	30	I½ to O
Grinding shear knives	30 to 36	A½ to M
Surfacing sides of circular saws	36 to 60	A½ to M
Rim bands on carriage hubs	36 to 46	I to O
Brass car boxes	30 to 36	I½ to O½
Grinding ends of spiral springs	46 to 60	I¾ to O½
Leveling off rivet heads	30 to 36	I½ to O
Fine grinding and tool finishing		
Universal grinding machine		
Sharpening small machine-shop tools	60 to 80	M to P½
Sharpening reamers and taps	60 to 100	A¾ to M½
Sharpening milling cutters	60 to 100	A¾ to M½
Grinding chilled rolls	36 to 46	A½ to M½
Finishing chilled rolls	60 to 100	A½ to M
Grinding leather splitting knives	90	A½

TABLE 17.—SAFETY EMERY WHEEL COMPANY'S TABLE FOR SELECTION OF GRAIN AND GRADE—*Continued*

Class of work	Number of grain	Grade
Fine grinding and tool finishing		
Brass finishing	60 to 100	M
Dental and surgical instruments	46 to 100	M to P½
Grinding and concaving razors	70 to 100	A½ to M
Grinding shoe knives	70 to 90	P½ to I
Fine hardened steel tools	80 to 120	A½ to M½
German silver	80 to 120	M to P
Shoe cutting dies	60 to 80	P to I
Ends of steel wire	70 to 90	P½ to I½
Internal grinding (finishing)	60 to 100	M to M½
Grinding lathe centers	60 to 80	M

TABLE 17.—SAFETY EMERY WHEEL COMPANY'S TABLE FOR SELECTION OF GRAIN AND GRADE—*Continued*

	Vitrified process	Silicate process	Elastic process		Vitrified process	Silicate process	Elastic process
Very soft	G	½	½E	Medium hard	P	4½	4½E
	H	¾	¾E		Q	5	5 E
	I	1	1 E		R	6	6 E
Soft	J	1½	1½E	Very hard	S	7	7 E
	K	2	2 E		T		
	L	2½	2½E		U		
Medium	M	3	3 E	Extra hard	V		
	N	3½	3½E		W		
	O	4	4 E		Z		

TABLE 18.—AMERICAN EMERY WHEEL WORKS' GRADE LIST

Class of work	No. of grain	Grade of hardness
Dies, surfacing	36	N
Knives, planing mill and paper cutting	24 to 36	1½
Milling cutters	46 to 80	J or 1½
Milling cutters, high speed steel	46	1½E
Rolls, chilled iron, roughing	36	N
Rolls, chilled iron, finishing	90	2½E
Saws, gumming and sharpening	36 to 60	M or 2½E
Steel, soft, cylindrical grinding	24 comb or 54	L to M
Steel, tempered, cylindrical grinding	36 to 60	K
Steel, tempered, internal grinding, roughing	46 to 60	K
Steel, tempered, internal grinding, finishing	80 to 120	J to K
Steel, tempered, surface grinding, disk-wheel	30 to 46	1½ or J
Steel, tempered, surface grinding, cup wheel	24 to 30	½ to ¾
Taps and reamers	46 to 60	J to K
Twist drills	36 to 46	K to M
For hand grinding		
Agricultural instruments, edging and jointing	16 to 24	Q
Brass castings	16 to 30	O to P
Bronze castings	16 to 30	P
Drop forgings	16 to 24	Q
General machine shop use	24 to 36	O to P
General rough grinding	16 to 30	P to Q
Hollow ware, inside grinding	36	P to Q
Iron castings	16 to 24	Q to R
Iron castings, chilled	16 to 24	R
Knives	36 to 60	M
Lathe and planer tools, dry	36 to 46	O
Lathe and planer tools, wet	30	4
Lathe and planer tools, high speed steel, wet	24	3½
Malleable iron castings	20	P to Q
Plow bodies, surfacing	16 to 24	O to P
Plow points	16 to 24	P to Q
Sheet steel, edging	24 to 30	Q
Small tools	46 to 100	N to O
Steel castings	12 to 20	Q to R
Stoves, finishing edges	36	Q to R
Stove mounting	20 to 30	Q to R
Structural steel	16 to 20	Q to R
Twist drills	46 to 60	M to N
Wood working tools	46	M or 2½E
Wrought iron	16 to 24	Q

TABLE 19.—AMERICAN EMERY WHEEL WORKS' TABLE FOR SELECTION OF GRAIN AND GRADE FOR AUTOMATIC (OR SEMI-AUTOMATIC) GRINDING

Kind of work	No. of emery or corundum	Degree of hardness	Grain and grade for exceptional cases	
			Sometimes as soft as	Sometimes as hard as
General machine work	30 to 36	3½ or 3½	3	.....
Saw gumming	36 to 46	2½	2	3
Large wheel water tool grinding	24	3½	.....	3¾
Small wheel water tool grinding	30	3½	3	3½
Large malleable castings	16	3¾	.....	4
Small malleable castings	20	3½	3½	3¾
Chilled iron castings	16	3¾	3½	4
Wrought iron	16	3¾	3½	.....
Rough grinding, general foundry use	16	3½	3½	3¾
Brass castings	30	3	2½	3¾
Bronze castings	20	3½	.....	3¾
Lathe and planer tools	36	3½	.....	3¾
Small tools	60	3½	3	3½
Wood working tools	46	2½	2	3
Twist drills, hand work	46	3	.....	.....
Twist drills, special machine	46	2	.....	.....
Reamer, tap, milling cutters, etc., hand grinding	46	3	.....	.....
Reamer, tap, milling cutters, etc., special machine.	60	2	.....	.....
Stove mountings	20	3¾	3½	.....
Drop forgings	30	3½	.....	.....
Safe work	16	3¾	3½	4
Car wheel grinding	20	3½	3	4
Planing mill and paper cutter knives	30	2	.....	3½
Jointing and edging agricultural implements	16	3¾	3½	4
Grinding plow points	20	3¾	3½	.....
Surface work on plows	20	3	.....	3½
Large steel castings	16	3¾	3½	4
Finishing edges of stoves	36	3½	3½	.....

TABLE 20.—STERLING EMERY WHEEL MANUFACTURING COMPANY'S TABLE FOR SELECTION OF GRAIN AND GRADE

I—Very soft	O—Medium hard
J	P
K	Q—Hard
L	R
M—Medium	S
N	T—Very hard
U and W—Extra hard	

TABLE 21.—ABRASIVE MATERIAL COMPANY'S GRADE LIST

Class of work	No. of grain or degree of coarseness usually furnished	Grade letters or degrees of hardness usually furnished
Large cast iron and steel castings	14 to 20	P to Q
Small cast iron and steel castings	20 to 36	P to Q
Large malleable iron castings	14 to 24	Q to R
Small malleable iron castings	20 to 30	P to Q
Chilled Iron castings	14 to 24	R to T
Wrought iron	14 to 30	O to P
Brass and bronze castings	20 to 46	P to R
Rough work in general	14 to 30	P to Q
General machine shop use	20 to 46	O to P
Lathe and planer tools	24 to 60	N to O
Small tools	46 to 100	N to P
Wood-working tools	36 to 60	M to N
Twist drills (hand grinding)	36 to 60	M to N
Twist drills (special machines)	46 to 60	J to M
Reamers, taps, milling cutters, etc., hand grinding	46 to 100	N to P
Reamers, taps, milling cutters, etc., special machines.	46 to 60	H to K
Edging and joining agricultural implements	16 to 30	Q to R
Grinding plow points	16 to 30	P to Q
Surfacing plow bodies	20 to 30	M to O
Stove mounting	20 to 46	P to Q
Finishing edges of stoves	24 to 46	O to P
Drop forgings	20 to 30	P to Q
Gumming and sharpening saws	36 to 60	M to N
Planing mill and paper cutting knives	30 to 46	I to K
Car wheel grinding	20 to 30	O to P

TABLE 22.—ABRASIVE MATERIAL COMPANY'S TABLE FOR SELECTION OF GRAIN AND GRADE

	Vitrified and silicate process	Elastic process
Soft	C	½E
	C^1	1 E
	C^2	1½E
	C^3	2 E
Medium soft	D	2½E
	D^1	3 E
	D^2	3½E
	D^3	4 E
Medium	E	4½E
	E^1	5 E
	E^2	5½E
	E^3	6 E
Hard	F	6½E
	F^1	7 E
	F^2	
	F^3	
Extremely hard	G	

TABLE 23.—VITRIFIED WHEEL COMPANY'S GRADE LIST

SECTIONAL AND HARD CORNER WHEELS

The Safety Emery Wheel Company manufactures what is known as a "sectional" wheel, shown in Fig. 91. These wheels are composed of radial sections made up of different abrasives. By the combination of the two abrasives hard and soft sections are produced. This allows the softer sections to wear

FIG. 91. SECTIONAL GRADING WHEELS.

FIG. 92. HARD CORNER WHEEL.

slightly faster than the hard sections, thus producing a tooth effect with the harder sections to insure rapid cutting and long life of the wheel. The usual combination of the sections in these wheels is emery and corundum, but any desired abrasives may be employed.

Another type of sectional grinding wheel made by the same company is the "hard corner" wheel illustrated by Fig. 92. In this wheel the sides are of a finer and harder material than the center, the object being to insure fast cutting and prevent rounding of the corners. Such wheels are particularly recommended for the grinding of slots and corners.

THE SHAPES OF WHEELS

Although grinding wheels are manufactured in a great variety of shapes and sizes, there are a few general forms into which they may be grouped. Practically all of the hundreds of commonly used shapes made for the various types of grinding machines and for the different kinds of work come under some one of these classifications, the most common of which may be designated as "disk," "cup," "cylinder" and "saucer" wheels. These shapes and some of their modifications are included in the groups of wheels illustrated in Figs. 93 and 94. These wheels are in most cases made in numerous widths and diameters, and the dimensions given in any such instances merely show the proportions of one size of wheel selected as typical from the comprehensive lists of wheel manufacturers' products.

Of the wheels in Fig. 93, *A* and *B* are plain disks; *C* is an offset disk used on cylindrical grinders for grinding close up to a gear, collar, or piston head of large radius; *D* is a disk wheel for different makes of tool and roll grinders, *E*, *EE*, *F*, *G* and *H* are "ring" wheels which are modifications of the disk type. The two wheels *E* and *EE* are made on large iron centers and are for use on the Sellers tool grinders. The other ring wheels referred to are adapted for mounting on large iron centers, and all such wheels are for service on machines where only a limited reduction of wheel diameter is permissible.

The shallow cup wheel *I* is for drill grinders and the larger, deeper cup wheel *J* is of a type used extensively on knife-grinding machinery. Wheels of this shape and of suitable dimensions, are also used on roll and cylindrical grinders, and in the smaller sizes on cutters and reamer grinders.

The wheel *K* is a plain cylinder for grinding on the end the same as the cup wheels. Such cylinders are used in various proportions on vertical surface grinders, edge grinders, etc. They are held in ring chucks.

Cup and cylinder wheels are coming more and more into use and are already made in a great variety of diameters and widths. On certain classes of grinding operations they have marked advantages over the regular form of wheel as the same diameter is always maintained, thus avoiding the necessity of a change in speed, and the grinding is accomplished on a flat surface instead of one that is curved.

The cup wheel *L* is for the Pratt & Whitney vertical surface grinder. The method of mounting this wheel will be described later.

Referring to Fig. 94, the small wheels in group *M* are for internal grinding

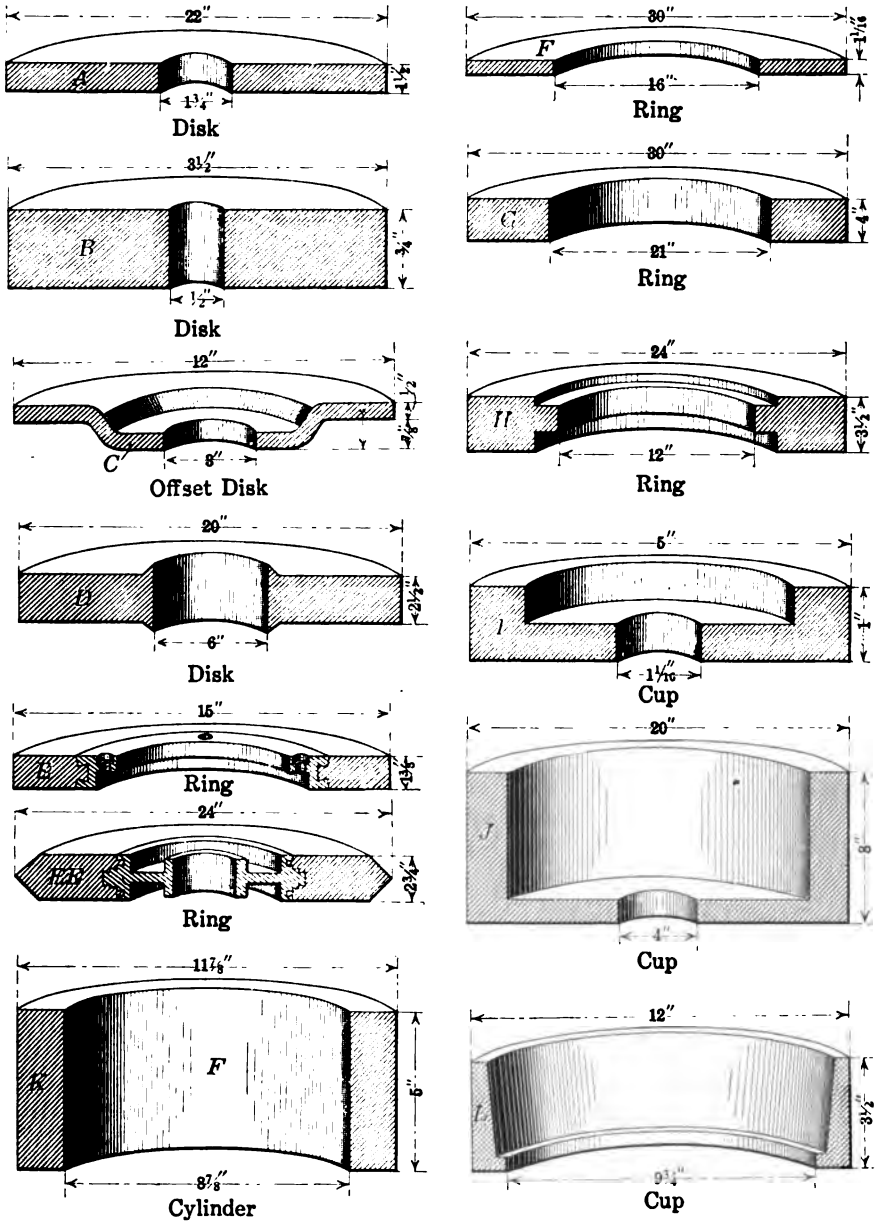


FIG. 93. SHAPES OF GRINDING WHEELS.

operations in holes of limited diameter. The larger internal wheel *R* is for Heald cylinder grinder Three forms of the "saucer" wheel for cutter grinders

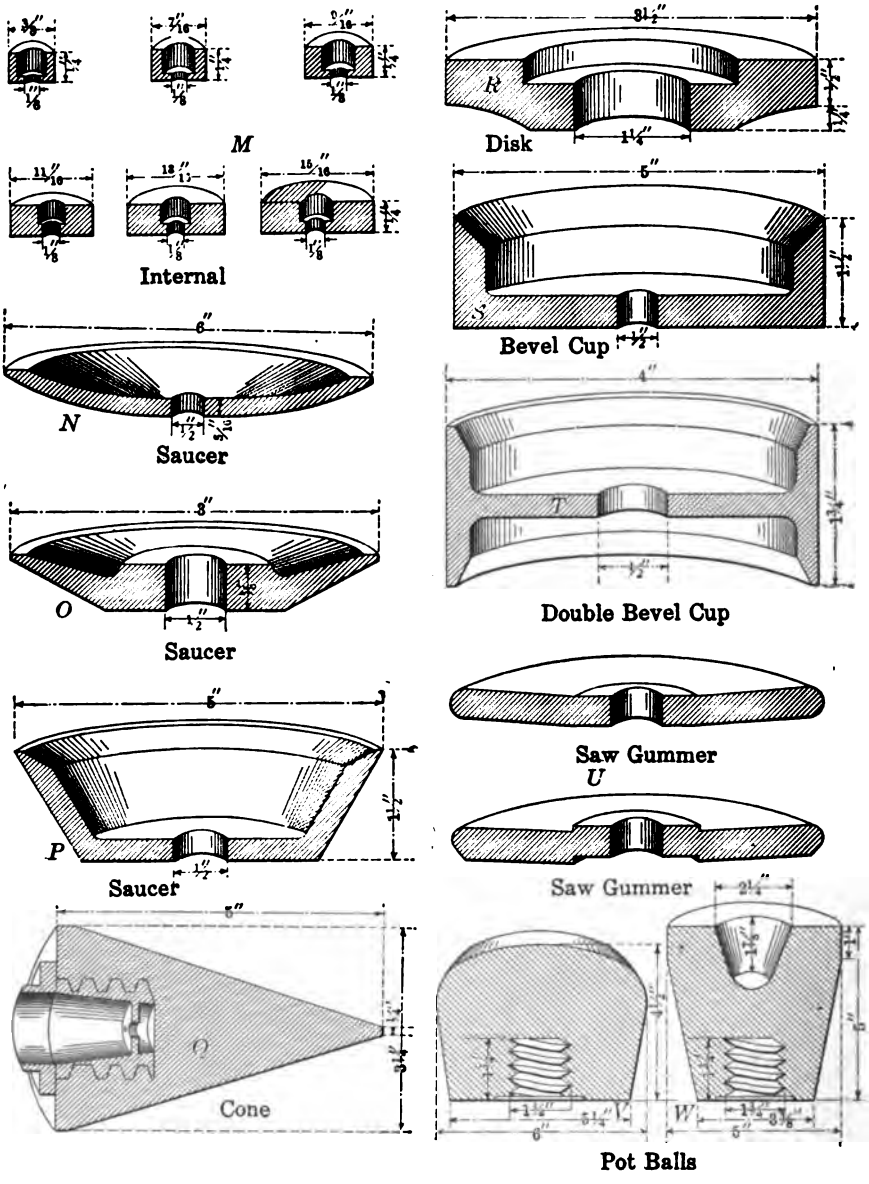


FIG. 94. SHAPES OF GRINDING WHEELS.

are lllustrated at *N*, *O* and *P*, and two bevel-edge cup wheels are shown at *S* and *T* both being made for cutter grinder use. The double-edge cup wheel

can be used for sharpening both sides of a straddle mill without reversing the latter on its arbor; it is also useful in such operations as grinding out parallel surfaces, say the jaws of a snap gage.

The conical wheel at *Q* is for a tool grinder and is used principally for sharpening pattern makers gouges which are beveled on the inside of the curve.

Two saw gummers, representative of a number of shapes regularly made, are shown at *U*. These are adapted for sharpening saw teeth and grinding down in the "gullet" or concave space between the bottoms of the teeth.

The "pot balls" at *V* and *W* are used in grinding out hollow ware such as pots and kettles. These are made in great variety so suit spherical receptacles, skillets, flat bottom pots, etc.

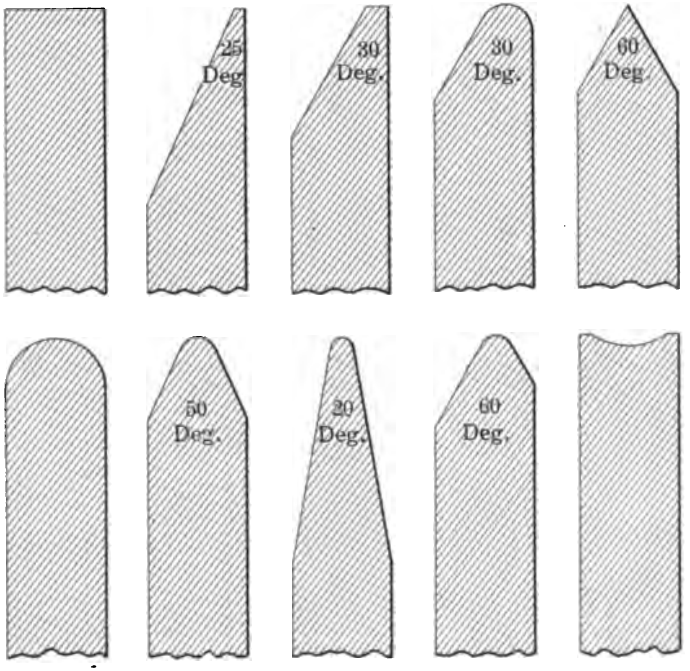


FIG. 95. STANDARD SHAPES OF WHEEL EDGES.

STANDARD SHAPES OF DISK WHEEL EDGES

In addition to the large number of wheel shapes necessary in cylindrical, surface, cutter and similar grinding operations, there are a great many simple modifications of the straight disk wheel for other purposes, consisting usually in a plain wheel with the edge dressed off convex or concave, or to such angles as 20, 25, 30, 50 and 60 degrees. These wheels are used for grinding molding cutters, gumming saws, etc. A number of typical shapes are reproduced in Fig. 95.

SELECTION OF WHEELS

The tables Nos. 11 to 23 for the selection of wheels have been compiled by the different manufacturers for the purpose of giving wheel users and dealers an approximate idea of what is most commonly furnished for various grinding operations on different classes of materials handled under the customary methods.

It is recognized that the conditions under which wheels are used vary to such an extent that no hard and fast rule is possible for selecting the grades best suited to the operations in hand. Such factors as the kind of machine used, the work and wheel speeds, the character of the material to be ground, whether the work is to be ground wet or dry, the nature of the contact between wheel and work, are all required to be taken into consideration. Therefore it is considered the best practice in the majority of cases to supply the wheel manufacturer with complete data regarding the work and working conditions, and leave the selection to him.

The Carborundum Company states that when selecting a wheel for any kind of work three considerations should determine the choice:

"1. The rapidity of grinding or cutting desired.

"2. The total amount of work to be performed.

"3. The finish to be produced.

"These three elements are usually of value in the order here given. The speed of a wheel and all other operating conditions being the same, they are influenced as follows:

"1. The rapidity of cutting is increased by using a coarser grit or a softer grade.

"2. The total amount of work performed by a wheel is increased by using a finer grit or a harder grade.

"3. The finish produced by a wheel is increased by using a finer grit together with a sófter grade."

DIFFERENCES OF OPINION AMONG WHEELMAKERS AND USERS

There is by no means unanimity of opinion among wheelmakers themselves, grinding machine builders, or operators in regard to the exact combination of conditions that must exist to finish work most economically on the grinder. The rigidity of machine and spindle; the diameter and length of work; the actual and relative speeds of work and wheel; the breadth of contact and rate of feed; the allowance left in turning for grinding; the amount left for the finish grinding passes; the relative hardness of work and wheels; the coarseness of the grain; these are some of the considerations that affect the results obtained by the grinding process.

Some experts believe in slow work speeds and fairly coarse, softer wheels while others run the work faster and use harder, finer-grain wheels. Much valuable information on the selection of wheels is given under the next heading, by H. Darbyshire, European demonstrator for the Norton Grinding Company.

THE WHEEL, THE MACHINE AND THE WORK

In one of his articles upon the subject of grinding machines and wheels, Mr. Darbyshire writes as follows:

Probably the greatest obstacle to the universal adoption of grinding processes is the difficulty of obtaining suitable wheels, yet their selection would seem to be a very simple matter. Improvements in abrasive wheels have kept pace with the development of the grinding machine, yet there is a marked lack of modern literature or instruction on the subject. For this both grinding machine and wheelmakers are much to blame and even where treatises are provided they would be much improved by being more explicit. On the other hand, users of grinding machinery should learn to think for themselves and not place too much reliance on the wheel salesman as often he can only recommend a wheel from what he has heard of its performance in some individual case, which might be quite opposed to the conditions under which the purchaser requires to use it.

There are many peculiar phenomena which take place in the action of abrasive material that are difficult to account for and for which a more superficial observation is insufficient. The want of a standard of grading, which should not be impossible to establish, leads to a confusion of ideas on the whole subject which would seem to be quite unnecessary if wheelmakers would coöperate to provide for it. Grinding processes now enter so largely into our industrial arts that the whole matter deserves a full and scientific analysis and here is an opportunity for our universities to make interesting and useful research; meanwhile, until something of the kind is done, there will always be the matter of prejudice to combat.

CHOOSING SUITABLE WHEELS

We now come to the question of choosing suitable wheels for various materials and processes of machine grinding, and here comes the difficulty and want of a standard and of a universal method of grading. Of the many firms engaged in the manufacture of grinding wheels there are probably no two which have a similar method of grading or designating the hardness of their wheels. The Norton Company, which is probably the oldest in the field, uses the letter method, which may be said to be the simplest. That is, they take M for their medium-hard wheel and the letters before M denote in regular alphabetical progression the progressively softer wheels. Moreover they use a + mark for denoting wheels which vary in temper from the standards. Thus a wheel may be harder than the standard K, let us say, and still be not so hard as the standard L; in this case it is known as K+. The Carborundum Company adopts a somewhat similar method of grading, the difference being that although M denotes its medium-hard wheel the letters before M denote the

progressively harder grades. Various other American companies use the letter method of grading to some extent, but all have individual ideas as to what degree of hardness should constitute an M or medium-grade wheel. Then we have firms both in America and on the continent of Europe which discard the letter method of grading or else use it in conjunction with numbers or fractions of numbers such as 2H, 1 1/2M and so on. All this is bewildering to the user of wheels and constantly gets him into difficulty. It very often happens that the maker and user are separated by long distances and the changing or obtaining of a suitable wheel means long delays and consequent loss.

The doubtful advantage to the wheelmaker of this state of chaos is that when a customer is educated to his special method of grading he will hesitate at trying his competitors' wares for fear of the trouble and confusion that may arise. But there is another side to the question. The writer knows of many instances where engineers are either conscious of the value of grinding processes or have ventured on the installation of a small plant, but the trouble with wheels has on the one hand made them afraid to commence the practice, and on the other it has either fallen into abeyance or not been carried out to the extent it seemed to deserve for the reasons stated.

STANDARD GRADING OF WHEELS

Individual enterprise would seem to show that firms would come into line with a standard and international method of grading, as may be gathered from the following instance, which is not uncommon. A firm of continental wheelmakers found that its sales were much restricted by its cabalistic method of grading when dealing with people who used the Norton wheel exclusively. As a simple matter of business they procured samples of most of the Norton wheels and compared them with their own for hardness. The result was a circular issued to the firms interested, the substance of which was a comparative table showing how its wheel compared with the Norton.

The selection of suitable wheels for machine grinding may be said to be governed by the following points, namely, the texture of the material to be ground, the arc of wheel contact with work and the quality of finish required. The first and last of these points can for convenience' sake be taken in conjunction, and here let it be understood that the quality of surface finish is dependent on the condition of the wheel face and depth of cut rather than on the fineness of the grit in the wheel. To make it still more clear, a wheel of so fine a grit as 100 will give an indifferent finish if it be not turned true and smooth.

It may be assumed that for all general purposes the aim in view is to procure a wheel which will fulfil two conditions, that is, that it shall first remove stock rapidly and at the same time give a decent finish. Wheels made from a combination of grit of different sizes are the best for this purpose, as may be seen from the following explanation. Coarse wheels of an even number of grit will

remove stock faster than will fine wheels of an even number, because their depth of cut or penetration is greater. They, however, fail in giving a high surface finish except in grinding very hard material, because they are not compact enough.

THE COMBINATION GRIT WHEEL

With the combination wheel the conditions are different and it seems better at removing stock than does the coarse, even grit wheel. It may be safe to assume from this that something of a *grindstone action* takes place, that is, that the finer particles of grit become detached from the bond and both roll and cut in their imprisoned condition between the larger particles. For finishing purposes this wheel has all the compactness and smooth face of a wheel which was made solely from its finest number of grit; and for roughing, it enables a depth of cut to be got which is within the capacity of its largest kernels.

With regard to the texture or hardness of material ground it may be taken as a general rule that the harder the material is, the softer the bond of wheel should be and that cast iron and hardened steel bear some relation to each other as far as grinding wheels are concerned, for the same wheel is usually suitable for both materials.

Too large an assortment of wheels is likely to lead to confusion, and we may take the Norton plain cylindrical grinding machine as being a case in point of a limited assortment of wheels; at the same time it will be a starting-point to illustrate choice of wheels under various grinding conditions. In this machine four different grade wheels, all of 24 combination grit, are found sufficient for all classes of material that it is ordinarily required to grind. This includes high- and low-carbon steels, cast iron, chilled iron, and bronze or composition metals. These wheels are graded J, K, L and M, and even the hardest of these, M, is superfluous. A 24 M wheel is only suitable for the softest of machine steels, yet it has to be supplied as an antidote to ignorance, prejudice and want of experience. It is generally called for in the belief that it lasts longer and so does more work than its next softer grade, though this need not necessarily be so. A wheel that is too hard must be repeatedly dressed with the diamond, which is one way of wearing it out, and diamonds themselves are expensive enough to be a consideration.

ONE ADVANTAGE OF GRINDING

One of the greatest advantages accruing from grinding is that it ignores the nonhomogeneity of material and that it machines work with the lightest known method of tool pressure, thus avoiding all those deflections and distortions of material which are a natural result of the more severe machining processes. Yet these objects are too often defeated by the craze for hard and long-lived wheels.

A wheel that is too hard or whose bond will not crumble sufficiently under the pressure of cut will displace the work and give rise to many unforeseen troubles. It is also a prolific cause of vibration which is antagonistic to good and accurate work. The advantage claimed for it, that it gives a better surface finish, is a deceptive one, for it mostly obtains this finish at the expense of accuracy. Quality of finish, that is, accurate finish, is merely a question of arranging of work speed, condition of wheel face and depth of cut. In the machine mentioned the suitability of wheels to materials and conditions is found to be as follows, the wheels being in each case of a combination of alundum grit:

For hard chilled iron and large diameters of cast iron and hardened steel..... 24 J
For medium chilled iron and medium diameters of cast iron and hardened steel and bronze..... 24 K
For all grades of steel which are not hardened and for bronze... 24 L
For very low carbon machine steels..... 24 M

The table given may, speaking generally, be what would be chosen in the way of wheels for the materials given, and in actual practice they soon give evidence as to whether they are suitable. It may be gathered from the table that diameter of work is a factor in the choice of a wheel. This refers to area of wheel contact and is governed by what is shown in the table when broad differences of diameter occur; for instance, it might be necessary to use the K wheel for a large diameter of high carbon steel if the L wheel was evidently too hard. One great reason for the success of the Norton machine is the practice of using the softer bonded wheels together with provisional points in its design, such as its massive construction and the wheels employed tend to obviate vibration. Soft wheels require that the work shall revolve slowly and this is compensated for by the broad wheel face and its rapid and easily controlled side feed; its wheels run at a constant speed, and are limited in number and variety, so that its numerous and rapidly arranged changes of work speed are an absolute necessity apart from their other economical advantages. These numerous changes of work speed enable the efficient cutting of any given wheel under broader conditions than would be otherwise possible, so that one wheel answers a number of purposes. At the same time the quality of finish is mostly dependent on work speed and its provision for rapid changes of these is at once apparent. When once the method of grading of a line of wheels be understood, their selection for all ordinary purposes is a simple matter if a little reasoning be indulged in.

SPEED AND EFFICIENT CUTTING

The efficient cutting of a wheel depends very much on the speed of the work, and an absence of knowledge in this respect may often lead to a suitable wheel's rejection. Revolving the wheel at the speed recommended by the maker is the

first necessity, and if it is found unsuitable after experimenting with various speeds it should be changed for a softer or harder one as the conditions indicate. Starting from the point that a wheel is desired that shall remove the maximum amount of stock with the minimum amount of wear on the wheel, the indications and method of procedure may be as follows; only it must be understood that this refers to cases where an ample supply of water is being delivered at the *grinding point.*

If after trying all reasonable work speeds, a wheel should burn the work, or refuse to cut without excessive pressure, or persistently glaze the surface of the work, it is too hard for that particular work and material and may be safely rejected. If after trying all reasonably reduced work speeds, a wheel should lose its size quickly and show all signs of rapid wear, it is too soft for that particular work and material and may be rejected. These indications refer to all ordinary cases and it may be gathered that the most economical wheel is that which acts in such a manner as to be a medium between the two cases There is still another point to bear in mind with regard to the size of the grit in the wheel, but which refers more especially to very hard materials such as chilled iron. Either a coarse or combination wheel may go on cutting efficiently in roughing cuts because pressure is exerted, but may begin to glaze when this pressure is much relieved as in finishing cuts. A careful microscopic scrutiny of a wheel that displays this tendency would seem to lead to the following assumption:

WHEN A WHEEL IS SHARP

The wheel face when newly trued with the diamond tool, which is necessary to obtain an accurate finish, shows a promiscuous arrangement of particles, some of which present points and others present a broader face with a rough and granular surface. When the wheel is presented to the hard surface of the work the high points of this granular face and the sharp contour of the kernels will go on cutting until they are dulled and worn down, after which their face area is too great to enter the surface without undue pressure. When the wheel has reached this condition the microscope shows these broader-faced kernels polished to a metallic luster, which bears out the explanation tendered and also makes the remedy quite apparent. This is to use a wheel of very fine grit for finishing purposes in these cases or else keep the coarser wheel in condition by repeated dressings with the diamond tool.

We now come to the question of wheel contact, and will take two extreme cases to illustrate how misunderstandings can easily, and often do, exist. A wheel may be asked for that is suitable for grinding machine steel, and the wheel agent or salesman offers one that has some reputation for efficiency in grinding that material. It may be that its reputation has been earned in the grinding of steel shafts of from small to medium diameter, and that the purpose for which it is asked for is the grinding of flat steel strips of percisely the same

material, yet for this purpose the wheel would almost certainly be unsuitable and would require to be of a softer grade or bond.

A reference to Fig. 96, will show what actual practice requires in the choice of a wheel as far as the question of wheel contact is concerned. A wheel is shown in contact with four different varieties of work, all of which we will suppose to be of the same material, the depth of cut, much exaggerated, being the same in each case. In the first case, it is a shaft of small diameter, and the wheel contact being the smallest the harder grade of wheel would be suitable, comparatively speaking. Assuming that this wheel was found to be suitable

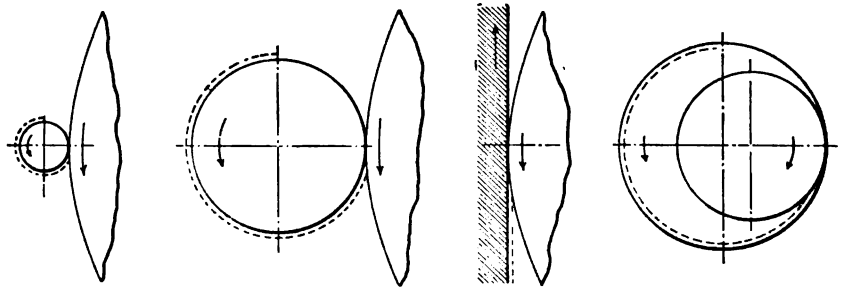


FIG. 96. WHEEL CONTACT WITH DIFFERENT WORK.

it would probably require a softer wheel for the next case, which is a shaft of larger diameter and the wheel contact proportionately greater. To continue the comparison still further the third case shows the wheel engaged in grinding a flat surface, and the fourth is a wheel grinding internally. In each case practice demands that the the wheel shall be progessively softer in bond or grade and this is some proof of a consistency in the action of grinding wheels.

THE CONTACT AREA OF WHEEL

The most probable explanation of this may be that as the contact area increases more work is required from each individual kernel of grit and it the sooner becomes dulled; this requires that the bond must be more friable both to allow it to escape easily and to minimize the pressure required to make the wheel cut as the cutting area becomes greater. Following on this reasoning we are able to choose a list of wheels that would be suitable for almost all purposes, and which would be as follows if of Norton grade:

For plain cylindrical grinding, J K L M.

For grinding plane surfaces, H I J K.

For internal grinding, F H I J.

This collection of wheels would be suitable for almost any type of grinding

machine, though when the wheels are exceptionally narrow a grade or one-half grade higher might be possible; it would, of course, be a matter for a little trial and experiment. The wheels for external cylindrical work may preferably be combination wheels, but for plane surfaces and internal work they are better made of single grit, about 36 or 46. The great contact area of wheel in these two classes of work is liable to generate much heat so that an open and porous wheel is preferable. The method of reasoning in choosing a wheel here advised, is one that has served the writer in some few years of experience and the Norton method of grading has been chosen for illustration because it is considered the simplest and most generally understood; the same line of reasoning, however, would serve with any other method of grading when the wheel user became conversant with it.

Briefly speaking, the matter of wheels being true to the symbol of grade that they represent, and the ability of their maker to duplicate them are of equal or greater importance than their prime constituents. It goes without saying that they should be both balanced and homogeneous in their construction, all of which are points for the user's consideration when placing his orders. Finally, avoid hard wheels above all things; and don't get the idea that their long life or promise of the same is an economic advantage. Rather, educate yourself to the use of soft wheels with work speeds and other conditions to suit them, and grinding will prove of better quality with less aggregate cost.

WHEEL PRESSURE AND WEAR

As the wheel is a disk built up from a numerous assortment of minute cutting tools which are held in position by a more or less friable bond, in using it we must bring it to bear on the work with a pressure that shall not be so great as to tear these minute tools from their setting until their cutting efficiency is exhausted, for if we do so we are wasting the wheel. To gage the exact amount of the pressure required is a matter of judgment and experience, though where automatic feeds are provided on a machine the right amount of pressure or feed is soon determined. It will also be readily understood that a regular automatic feed is more reliable for the purpose than a possibly erratic hand one. The automatic feed may be set to give a certain depth of cut at each pass of the wheel, and its amount of wear noted; if this wear be found excessive the depth of cut may be reduced. It must not be here forgotten that work speed also enters into this consideration and that a high work speed will tend to wear the wheel excessively; inversely a reduced work speed will reduce the amount of wear. Having those points in mind the right combination of depth of cut and work speed is soon arrived at, and an approximate judgment attained for the future.

GRINDING ALLOWANCES

The amount of stock left for removal by the grinding wheel and the method of preparing the work have both much bearing on the economic use of grinding

wheels; heavy and unnoticed losses often occur through want of a few precautionary measures. The necessary amount of stock to leave on a piece of work as a grinding allowance depends first, on the type of machine employed, the class of labor engaged in preparing it and whether it has to be hardened or otherwise.

In powerful machines which will remove stock rapidly, the grinding allowance may be anything from 1/32 to 1/64 in. This broad limit allows of expedition in the preparation of work in the way of coarse feeds, nor does it necessitate the same skill in preparation as would a more refined limit; but its maximum should not be exceeded unless there are special circumstances to warrant it.

There are many cases of an especial character when the grinding allowance stated may be exceeded to advantage so long as discretion is used. Straight shafts may often be ground direct from the black bar of raw material 1/16 in. above finished size, or when shafts of this character must have large reduction on the ends, they can be roughly reduced in the turret lathe while in their black state and finished outright more economically in the grinding machine. Very hard qualities of steels or chilled rolls are other cases where it is often more economical to use the grinding machine without any previous machining process, and though there may be sometimes an alarming waste of abrasive material its cost is as nothing compared with other savings that are made.

It is at present an accepted fact that the use of high-speed steel obviates the necessity of casting or forging to the limits which were necessary before its introduction, it being found cheaper to bring the work to shape in rapid reduction lathes and other machine tools. The writer, however, has seen many examples of which the forging and casting were arranged for grinding without any previous machining and with extremely profitable results on work of a somewhat limited size. Grinding allowances for hardened work are usually larger than for soft work, to allow for possible distortion; so that individual experience alone can determine the amount to be left. It is sufficient to say that the allowances on case-hardened or carbonized work should not be too excessive; otherwise the hardened surface may be ground away.

GRINDING HARDENED WORK

As far as the actual grinding of hardened work goes, it is indispensable that the whole portion of a piece that is to be ground should be roughed over previous to the final finishing; if it is at all possible to allow some little time to elapse between the two operations so much the better, more especially if it has bent in hardening and been afterward straightened; this will allow of the development of any strain that may be present. Both for a special and standard work in a factory a table of grinding allowances can be compiled as a result of experience and posted in a conspicuous position. If this be done and trouble

taken to see that it is adhered to, it will save much trouble and be a means of avoiding much unnecessary expense.

Mention should be made of the necessity of slightly undercutting the corners of shoulders so as to preserve the corner of the grinder's wheel intact. A piece of work prepared in such a manner as will form a radius on the corner of the wheel is an abomination, for to get the wheel face flat again means much waste of wheel and wear of diamond tool. Where fillets or radii are necessary they are better got out with a tool, for even if they are to be ground they must be turned good to allow the wheel to conform to their shape. The only excusable reason for grinding a round corner is when the work is hardened or in some special case where the expense incurred is warranted.

WHEELS IN USE, A GUIDE TO THE SELECTION OF NEW WHEELS

It has been pointed out in this chapter, that, as the conditions governing the uses of grinding wheels vary, so must the grain and grade. However, we can learn much from what different shops are using in the way of wheels for specific jobs and such information should be of considerable assistance when the selection of a wheel for some similar class of work is under consideration.

Along this line, the Norton Company publishes in *Grits and Grinds* a great many useful items in reference to their wheels in service, as gathered from the people who are actually using them. These brief reports show just what grain and grade are being successfully used for, a specified operation, give the diameter and width of the wheel and in many cases the name of the machine on which the work is accomplished. A number of these items which should be of general interest and value, are given below:

THE WORK AND THE WHEEL

Cylindrical grinding, cast iron; 14 by 5-in. alundum wheel, "30-J" silicate.

Cast-iron valves, 3 to 6 in. diameter, 24 in. long; 14 by 3/4 by 5-in. alundum wheel, "24 Combination, grade K" (wet grinding).

Cast-iron drill press plates, grinding flat side; 8 by 1 1/2 by 2-in. alundum wheel, "50–I" (Brown & Sharpe grinder).

Gray iron castings, finishing, off-hand grinding; 14 by 1 1/2 by 1 1/4 alundum wheel, "60–O." Castings left rough by a coarse wheel and No. 60 used for polishing.

Malleable and steel castings, roughing out; 16 by 4 1/2 by 7, 2-in. rim "20–Q" cylinder wheel used in a chuck on the spindle of a disk grinder.

Malleable iron implement castings, weighing 2 to 20 lbs; removing small fins; 18 by 1 1/2-in. alundum wheel, "30–R."

Cast-iron soil fittings; 20 by 2-in. wheel, "24–P."

Chilled car wheels, double flanged; 12 in. up to 18 by 2-in. wheels, "20–Q."

Chilled iron blocks, 6 by 12 in. surface ground on automatic machine; 12 by 1 1/2 by 1 1/4-in. wheel, "30–N."

Chilled iron brake shoes; 18 by 3 by 2-in. alundum wheel, "20-Q."

Drop forged flanges, grinding fins; 16 by 2-in. alundum wheel, "24–R."

Forgings for surgical instruments; 24 by 2-in. wheel, "36–P."

Rough steel castings, ground on surfacing machine, also off hand on regular grinder; 16 by 2 1/4-in. alundum wheel, "16–S" vitrified.

Drop forgings for wrenches, grinding fins; 14 by 1-in. alundum wheel, "30–Q."

Soft steel carriage axles; 18 by 2 1/2-in. alundum wheel, "24–Q."

Files, grinding edges and tangs; 12 by 3/4-in. wheel, "46–Q."

Files, grinding on Pratt & Whitney surface grinder; 12 by 4 1/2-in. cup wheel with 1 3/8-in. rim; alundum wheel, "30–H" silicate.

Cold metal saws; 8 by 1/2-in. and 8 by 5/8-in. wheels, "50–Q."

The wheel is mounted on a swinging arm and passed back and forth across and above the saw.

Steel ball races; 2 1/2 by 1/4-in. alundum wheel, No. 60, grade 4 elastic. An internal operation on the Rivett grinder.

Sheet steel scraper plates, grinding edges; 18 by 2-in. alundum wheel, "30–Q."

Cams, 7/8 in., hardened steel, 0.025 in. to be removed; 11 by 1 1/4 by 5-in. alundum wheels, "46–M" and "46–N," both satisfactory, "N" being the better (Landis grinder).

Disks, 110 to 120 point carbon steel, 12 to 18 in. diameter; an 18 by 3-in. alundum wheel, "36–U," ground over 110,000 of these on the edge.

Locomotive guides; 12 by 4 by 7 1/8-in. wheel, "30–L" silicate.

Structural steel, removing burrs left by presses and shears; 36 by 4 by 21-in. alundum wheel, "16–R" silicate.

Sewing machine spindles, cold-rolled steel; 12 by 1/2 by 5-in. alundum wheel, "60–N."

Small drills; alundum wheel, "60–O."

Hardened and high-speed steel, ground on Pratt & Whitney surface grinder; "30–H" vitrified wheel.

Cutting off on the Slack machine; "60–3" elastic wheel.

High-speed steel tools on wet grinder; "24–P" silicate wheel.

General tools on Diamond wet grinder; 24 by 3 1/2 by 10-in. silicate wheel, "20–P."

Brass castings; "30-O" silicate wheel. Also "46–O" vitrified.

Bronze bushings; "60–M" silicate wheel.

Brass and copper; 10 by 1 1/4-in. alundum wheel, "36–P" vitrified.

Aluminum, brass and bronze, on Pratt & Whitney surface grinder; elastic wheels, "30– grade 1 1/2."

Aluminum gas engine cases; 18 by 2-in. alundum wheel, "36–4" elastic.

WHEELS FOR GRINDING CRANKSHAFTS

The Norton Grinding Company recommends for use on its plain grinders on crankshaft work the following wheels: 24 combination, grade N vitrified, for roughing, and 24 combination, grade M vitrified, for finishing.

For 14-in. Norton plain machines for crankshaft grinding, the wheels should be ordered with 12-in. holes unless the face of the wheel is less than 2 in. wide, in which case the order should invariably specify 5-in. hole. The thickness or width of the face of the wheel depends somewhat upon conditions.

The finishing wheel in all cases should be ordered 1/32-in. wider face than the length of the pin or bearing to be ground. For example, if the pin or bearing is 2 1/2 in. in length between shoulders the face of the finishing wheel should be 2 17/32 in.

When the crankshafts are ground from the drop forgings without turning the shoulders of pins or bearings in the lathe, the grade N wheel should be used with the face 1/32 in. wider than the length of the pin between shoulders. If, however, it is necessary to turn the shoulders of the pins and bearings in the lathe, a roughing wheel (grade N) with face 1/4 in. narrower than the length of the finished pin should be used.

The reason for the extra thickness of the finishing wheel is to allow 1/32 in. for truing off with the diamond after the wheel is mounted in its collet, in order to get the wheel to run perfectly true both on the sides and the face.

Note the following examples: Wheels for grinding crankshafts where the length of the finished pin is to be 2 1/2 in., the crankshaft to be ground from the drop forging without turning the shoulders of pins or bearings in the lathe—

Roughing wheel 24×2 17/32 in. ×12 in., No. 24 combination, grade N.

Finishing wheel 24×2 17/32 in. ×12 in., No. 24 combination, grade M.

Wheels for grinding crankshafts where the length of the finished pin is to be 2 1/2 in., to be ground after having been turned in the lathe—

Roughing wheel 24×2 1/4 in. × 12 in., No. 24 combination, grade N.

Finishing wheel 24×2 17/32 in. ×12 in., No. 24 combination, grade M.

WHEEL COST A SMALL ITEM

It may be well as we approach the end of this chapter on the subject of grinding wheels to say a word in reference to "wheel cost," and here again we cannot do better than to quote from *Grits and Grinds*, as follows:

In many grinding operations the wheel wear (the first cost) is a small item of expense when compared with the actual cost of operation, in which we must figure the horse-power consumed, labor, machine investment and the production.

In order to obtain a fair idea of the "cost of wheel," an accurate record was kept of a grinding operation on a 10×72-in. Norton plain machine. The work was grinding 35-point carbon open-hearth machinery steel shafts from the black

stock, taking off 1/16 in., reducing from 1 3/8 in. diameter to 1 5/16 in. A 15×2 in., 24-L alundum wheel, was used and in 10 hours' work it showed but 0.270 in. wear. The wheel was trued once at the start and once at the end of 6 hours. The work speed was 25 ft. a minute; the wheel speed, 6100 ft. a minute; table traverse, 12 ft. a minute. That means a wheel cost of but a very few cents a week.

It is not good policy, therefore, when endeavoring to reach maximum grinding economy to let the price of a grinding wheel stand in the way of a larger production. Instead of thinking too much about "wheel cost," due consideration should be given to the other factors of cost—labor, which must be figured at from 60 cents to $1 an hour; the horse-power consumed in grinding; the production necessary to make the grinding machine investment a profitable one and the many advantages of rapid production. These are the factors that must be weighed carefully when purchasing grinding wheels. Compare them with the "wheel cost."

Economy consists in getting the right wheel for the work and operating it under the most favorable conditions, and the original cost of the wheel in most cases is too small an item to take into consideration.

POINTS IN ORDERING WHEELS

Users of grinding wheels can avoid unnecessary trouble and delay in securing wheels if orders are carefully and accurately made out with explicit information as to the character of wheels desired and uses to which they are to be put.

One of the European agents handling Norton wheels sends out an information blank to be used when ordering, which is found to be mutually valuable to customer, agent and wheel manufacturer.

Name of firm

Address

Quantity

Diameter

Thickness

Hole

If special wheels are wanted, please furnish sketch with necessary dimensions. If shown in our catalogue give number and name.

To be used on—standard, tool, or cylindrical grinding machines.

Kind of material to be ground.

(a) Material.

(b) If steel, whether hardened or unhardened.

(c) Large or small contact between work and wheel, surfaces, edges, fins or burrs (important in the case of cast- and wrought-iron pieces).

(d) Tool grinding. Kind of tools.

Method of grinding: Free hand, with work rest, automatic, cylindrical, internal surface, wet or dry.

Revolutions per minute of grinding wheel.

If cylindrical or internal grinding is to be done, give the r. p. m. of the work and diameter of the work.

Is the machine made to run at more than one speed, and if so, at what speeds?

Feed of work or wheel. (If cylindrical and internal grinding.)

Are large, medium or very small pieces to be ground?

Kind of finish desired, whether rough, medium, fine or polish.

Which grain and grade of Norton wheels, or which kind of wheels have been used heretofore for this work, and what satisfaction did they give?

Other remarks.

Be sure to state whether the wheel is to be used for grinding more than one kind of material, so that one may be selected which will be best adapted for the varied work.

The more complete the information, as above requested, is given, the better enabled we will be to select a wheel of grain and grade which will be most satisfactory for the work.

When reordering, give date of last order.

CHAPTER VII

MOUNTING AND DRESSING GRINDING WHEELS

One of the most important considerations in connection with the use of grinding wheels is that they shall be properly mounted, upon suitably proportioned spindles and between properly designed flanges. A wheel which is crowded upon a spindle of weak design, or which is cramped between two imperfect flanges that are either too small or take a bearing upon the wheel at the wrong point, is subjected to conditions as likely to cause an accident as is an excessive rate of speed.

MOUNTING WHEELS ON FLOOR GRINDERS

The vast number of abrasive wheels in use upon the class of machines commonly known as bench and floor grinders, grinding wheel stands, emery grinders, etc., and which are so generally in service at various points about the machine shop, blacksmith shop and foundry, makes it desirable that something should be said here in reference to the best methods of mounting wheels on such apparatus.

In the first place, the machine itself should be of rigid construction, with spindle of ample proportions; the bearings should be well fitted; and kept well oiled so that the arbor will not become overheated and by expanding, break the wheel; and the machine should be securely fastened on substantial foundations not only to insure safety but in order to secure better results with the wheel.

The following sizes of spindles are recommended by the Norton Company and by some other wheelmakers, except where the grinding wheels are extra thick:

Wheel	Spindle
6 in. diameter and less	½ in.
8 in. diameter and less	⅝ in.
10 in. diameter and less	¾ in.
12 in. diameter and less	1 in.
14 in. diameter and less	1¼ in.
16 in. diameter and less	1½ in.
18 to 20 in. diameter	1¾ in.
22 to 24 in. diameter	2 in.
Larger than 24 in.	2½ to 3 in.

The flanges should be relieved as in Fig. 97, and they should be at least one-half the diameter of the wheel and have a true bearing at the outer edge. The inner flange should never be loose but in all cases should be fixed on the spindle. Under no circumstances should the flanges be allowed to be less than

one-third the diameter of the wheel. Wheels must not be allowed to run when held only by a nut in place of a flange, as the nut is liable to crawl and cause accident.

Compressible washers of pulp or rubber, slightly larger than the flanges should be used between the flanges and the wheel. These distribute the pressure evenly when the flanges are tightened, by taking up any imperfections in the wheel or flanges.

The hole in the wheel bushing should be 0.005 in. larger than standard size spindles. This permits the wheel to slide on the spindle without cramping and

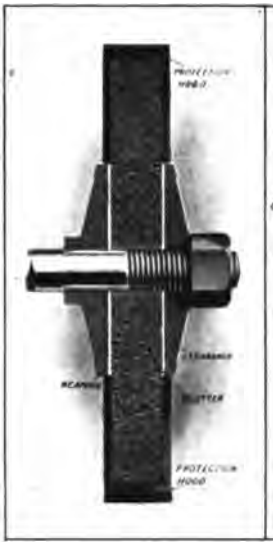


FIG. 97. CORRECT MOUNTING.

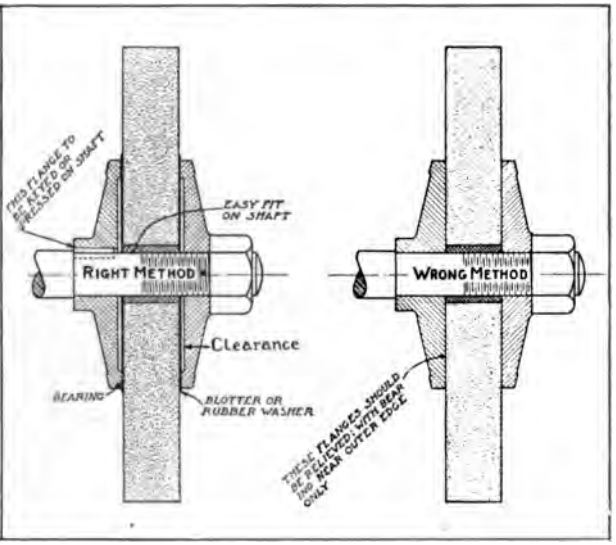


FIG. 98. RIGHT AND WRONG METHODS OF MOUNTING.

insures a good fit not only on the spindle but against the inside flange, which is essential.

The flanges should be tightened only enough to hold the wheel firmly, thus avoiding unnecessary strain. The importance of this statement is emphasized by the fact that on a 1 1/2-in. floor grinder equipped with 8-in. standard relieved flanges a man with a 2-ft. wrench can easily exert a crushing pressure between the flanges and wheel of 3600 lb.

RIGHT AND WRONG WAYS OF MOUNTING

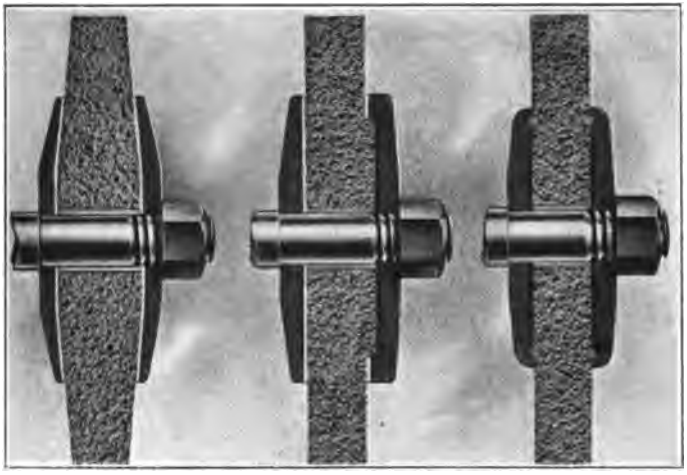
The Norton Company in a pamphlet on "Safety as Applied to Grinding Wheels" illustrates by the sketch reproduced in Fig. 98, the right and wrong methods of mounting grinding wheels. In the view to the left relieved flanges are shown with compressible washers between the flanges and wheel, and a perfect bearing around the outer edge. The view at the right shows the im-

proper method, straight flanges being used and no washers being applied between flanges and wheel.

When the nut on the spindle at the right is tightened it causes the straight flanges to become slightly convex and instead of the pressure being distributed evenly over the whole bearing surface of the flanges it is concentrated near the hole, creating a dangerous condition. The inner flange should never be left loose on the spindle as in this case but should be keyed or shrunk on.

The rest should be adjusted as closely as possible to the wheel to prevent the work from catching between wheel and rest.

Great care should be taken to keep the wheels perfectly true and in balance not only to avoid accidents but also to obtain the best results both as regards rapidity and accuracy of grinding.



BEVELLED FLANGES. SHOULDER FLANGES. RING FLANGES.

FIG. 99.

PROTECTION FLANGES

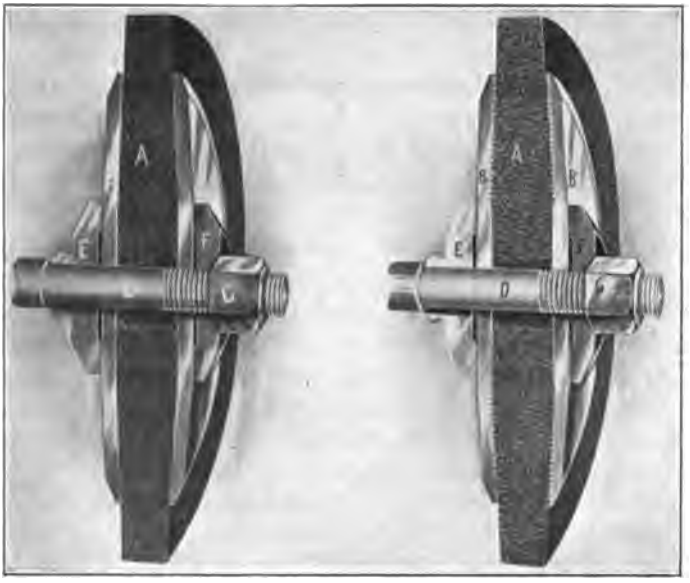
Protection flanges of various kinds with wheels to correspond, are made by different wheel manufacturers. Three types of flanges of this nature made by the Norton Company are illustrated in Fig. 99. As therein designated, they are known respectively as beveled flanges, shoulder flanges, ring flanges.

The inside flange must be fixed or keyed on as with the regular flange, and all flanges should be relieved. The largest diameter in the set of flanges must be used on the full-size wheel, and flanges on both sides of the wheels should be of the same diameter whatever the size of the wheel may be. When used without a protection hood not over 2 in. radius of the wheel should project outside the flanges.

In fact, it is desirable that wherever possible a protection hood should be used regardless of the make or shape of the wheel, whether straight-faced or beveled, for there is always the possibility that through some accident the portion of the wheel outside the flanges may be broken and the pieces if not caught with a hood cause serious injury.

SAFETY COLLAR SYSTEM

The protection flanges made by the Safety Emery Wheel Company are known as "safety collars" and are used with wheels of the "safety" shape manufactured by this company. The safety collar system is illustrated by Fig. 100. The wheels are convex on the sides with a flat spot 4 in. in diameter



SAFETY EMERY WHEEL. SAFETY COLLAR SYSTEM.

FIG. 100.

at the center. From this point out to the periphery they are turned tapered. The collars are also flat in the center and the inside is turned from the flat to the outer edge to a slightly different taper from the side of the wheel so that the periphery of the collar will bear on the wheel before the center touches. The collars are made with the inner faces plain or serrated as indicated by the two sections in Fig. 100. Two paper pads or washers are used with each wheel between the wheel and safety collars.

The inner collar *E* in this system is shrunk onto the spindle in the usual fashion, and the "safety" collars are tightened between this fixed collar and collar *F* against which the nut takes its bearing.

The makers recommend using from two to four sets of collars depending upon the size of the wheel at the outset. Thus as the wheel wears away in size the large collars may be replaced by smaller ones to hold the wheel at all times until it is worn out.

GRINDING WHEEL SPEEDS

At this point before considering wheel mounts on some other classes of grinding machines, it may be well to refer to the matter of speeds for grinding wheels. As already noted, cup and cylinder wheels by cutting on their ends, maintain a constant peripheral velocity irrespective of wear in service. But with disk wheels the wear on the periphery reduces the wheel diameter and as it is desirable that a constant peripheral speed should be maintained, as nearly as possible the speed of the wheel spindle should be increased to compensate for the diminished wheel diameter.

Complaints are sometimes made that wheels appear softer as they wear toward the center. This is caused by the wheel becoming smaller in diameter, and with the same spindle speed the periphery speed is reduced, thus causing the wheel to wear away faster and appear softer though in reality such is not the case.

The increase of the speed as the wheel wears away can be accomplished by different methods, *i.e.*, variable speed countershafts, cone pulleys on the spindle of the grinder or by transfering the wheels from the first grinder to smaller and faster machines as the wheels wear down. This last system has decided advantages, and is recommended where there is sufficient grinding to warrant the use of more than one machine. These grinders should then have but one large pulley on the machine, which removes all the possibility of starting up the new wheel, when full diameter at the highest speed. When the single pulley system is not employed, great care should always be taken to start up the new wheel on the slow speed.

If on some particular work the wheel does not operate satisfactorily it can often be made to do so by changing the speed. If it fills or glazes[1] a slower speed will sometimes give better results, while if the kernels are being loosened by the work, a slight increase in speed (if not already running at the limit surface speed prescribed for that particular size wheel) will usually prolong the life of the wheel, and improve its cutting qualities.

Speed tables and rules for obtaining surface speeds for wheels will be found at the end of this chapter.

POWER CONSIDERATIONS

Vibration due to frail spindles or machines that are not rigid, is wasteful both of wheel and power. The heavier the machine the softer the wheel can be. In order to use wheels on frail machines they must be made harder. Harder

[1] Glazing and loading of wheels are taken up in detail on page 159.

wheels require more power to produce the same work and consequently more pressure against the wheel by the operator.

POWER REQUIRED TO DRIVE WHEELS OF DIFFERENT SIZES

The table herewith shows maximum horse-power required to drive grinding wheels of various sizes. The figures are based on belt speeds and diameters and width of pulleys of the Norton Company's regular grinding machines of the bench and floor types, and represent what single belts on these machines will transmit. The absolute power required will vary according to the size of the work and the pressure at which it is applied. Although no fixed rule can be given the Norton Company finds from long experience that these figures cover the power required to do the heaviest work that can be performed on the respective sizes of machines.

Machine	Number of wheels	Max. diameter and thick. of wheel	Max. h. p.
Bench tool grinder	1	12×2 in.	3
Bench saw gummer	1	12×1½ in.	3
Single wheel grinder	1	30×4 in.	9.5
½ in. bench grinder	2	6×1 in.	1.5
⅝ in. bench grinder	2	8×1 in.	2
¾ in. bench grinder	2	10×1½ in.	3
1 in. bench grinder	2	12×2 in.	4
1¼ in. bench grinder	2	14×2½ in.	5.5
1¼ in. floor grinder	2	14×2½ in.	5.5
1½ in. floor grinder	2	16×3 in.	8
1¾ in. floor grinder	2	20×3½ in.	8.5
2 in. floor grinder	2	24×4 in.	9.5
2½ in. floor grinder	2	30×4 in.	9.5
3 in. floor grinder	2	36×4 in.	11

TABLE 24.—MAXIMUM H. P. REQUIRED TO DRIVE WHEELS OF DIFFERENT SIZES

Note.—The size of the machine in the first column refers to the diameter of the spindle.

MOUNTS FOR OTHER TYPES OF MACHINES AND WHEELS

The sketch, Fig. 101, shows an adjustable iron holder or center upon which the large wheels of the Diamond Machine Company's tool grinders are mounted. Such holders are accurately turned to insure balance; they are drawn up to clamp the wheel by a series of bolts.

Three shapes of wheels, with clamp centers, for the Sellers tool grinders and drill grinders are shown in Fig. 102. With these adjustable clamp centers when a wheel is worn out it is unnecessary for the users to send the centers

to the wheel makers to have new wheels made on them as is required with the older type of center made in one piece. The clamp center is made in two parts, a tight and a loose flange. To remove the wheel it is merely necessary to remove the bolts and take off the loose flange.

An adjustable cylinder wheel holder used by the Diamond Machine Company is represented by Fig. 103. The holder is designed to support the wheel close up to the cutting end, and consists of a body *D* which is tapered externally and

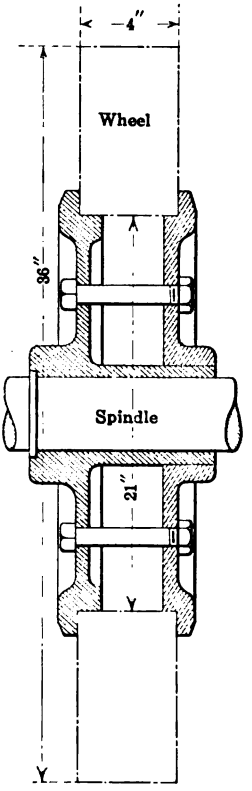
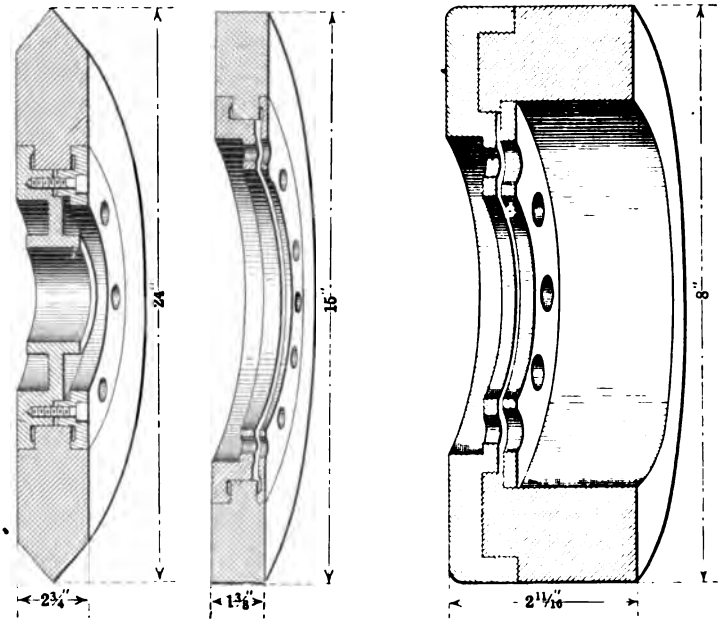


FIG. 101. ADJUSTABLE WHEEL HOLDER FOR WATER TOOL GRINDER.

split at various points about the circumference to allow the steel ring *F* to clamp the wheel when the nuts *B* are tightened. The cylinder wheel rests upon a follower plate *G* which is adjusted by screws *E* to advance the wheel in the chuck as fast as it wears away on the cutting end. The clamp ring *F* releases the cylinder for adjustment and holds it securely in its new position when again tightened.

Another cylinder wheel chuck, made by the Norton Company, is illustrated in Fig. 104. The cylinder is held in the chuck by means of a conical ring which is divided into segments, each segment being adjusted by means of screws as



TOOL GRINDER WHEELS. DRILL GRINDER WHEEL.

FIG. 102. CLAMP CENTERS FOR SELLERS TOOL AND DRILL GRINDER.

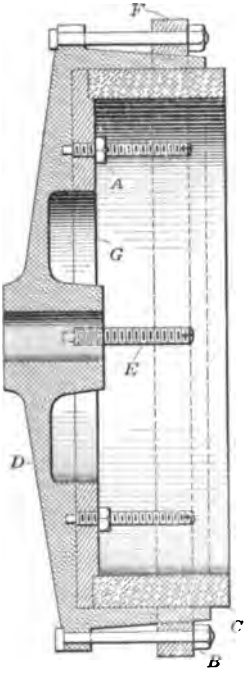


FIG. 103. DIAMOND MACHINE COMPANY'S CYLINDER WHEEL CHUCK.

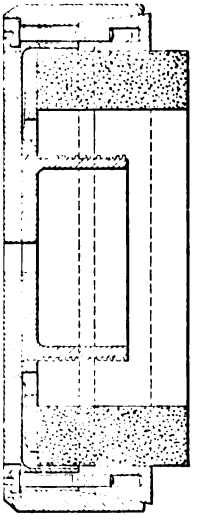


FIG. 104. NORTON COMPANY'S CYLINDER WHEEL CHUCK.

shown. The projection of the cylinder beyond the face of the chuck is controlled by means of a plate behind the cylinder, the plate being adjusted by means of a fork wrench. This plate also supports the cylinder after it has been brought into the desired position.

It is important that the cylinder be centered as nearly as possible when tightening the segments, in order that it may not run out and cause vibration of the machine.

METHOD OF MOUNTING A WHEEL ON A CYLINDRICAL GRINDER

A section through the wheel spindle and wheel of a Landis plain cylindrical grinder is illustrated in Fig. 105, showing the form of wheel mount employed and also the arrangement of the balancing weights with which this grinder is equipped.

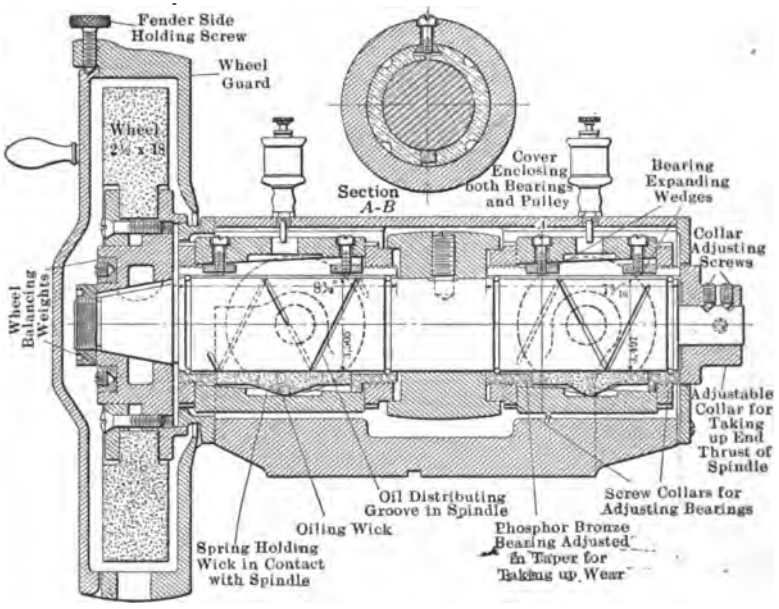


FIG. 105. SECTION THROUGH LANDIS PLAIN GRINDER—WHEEL, SPINDLE AND BEARINGS.

There are two of these weights or blocks which are carried as shown more clearly in Fig. 105, in a channel which runs all the way round in the face of the wheel center. The blocks are made of cast iron, are split at the bottom as seen at *A* Fig. 106, and have a pointed screw running in from the top which expands the blocks and holds them securely in any position.

When a wheel is brought into service and found to run unbalanced after being trued, it is taken from the machine with the center to which it is clamped, an arbor is inserted in the center hole and it is then placed on the balancing ways,

the balance blocks removed and the heavy side located. The blocks are then placed in the groove together at the top (the lightest side) and adjusted so that the wheel will stand in any position.

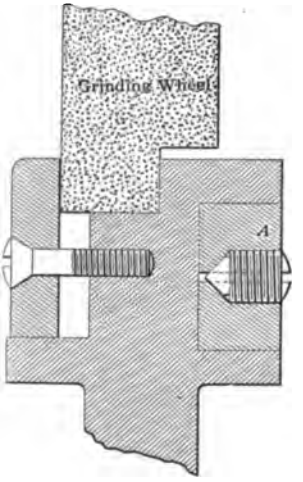


FIG. 106. SECTION OF LANDIS WHEEL CENTER AND BALANCING BLOCK.

A SURFACE GRINDER WHEEL MOUNT

The Pratt & Whitney vertical surface grinder spindle carries a wheel mount shown in section in Fig. 107. The cylinder wheel in this case is secured in its seat by shellac and by a narrow brass clamping ring. The instructions issued by the company for mounting wheels are as follows:

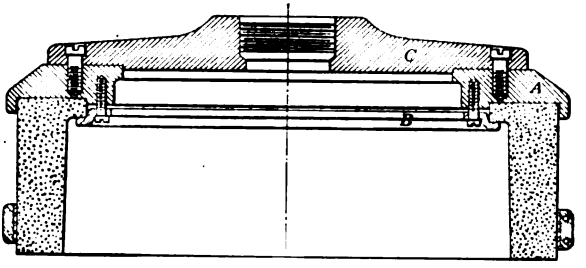


FIG. 107. SECTION THROUGH WHEEL DOWEL USED ON THE PRATT AND WHITNEY VERTICAL SURFACE GRINDER.

Remove the wheel mount *A* from the face-plate *C* by removing the screws Do not remove the face-plate from the spindle. Remove the ring *B*, and heat the holder *A* until the shellac runs. Remove the old wheel, and also all old shellac, using a scraper if necessary.

See that the new wheel fits freely in the groove. Put new flake shellac into the groove, and heat the ring slowly until the shellac is melted, taking care not to overheat the shellac. Warm the wheel to a comfortable handling heat, after which press it into the groove, and let it lie with a weight upon it until the ring and wheel have cooled sufficiently to let the shellac get a good hold on the wheel. Remove the wheel and ring from the flame and let them cool off together. Do not cool with water. When cooled put the brass ring *B* in place and tighten the

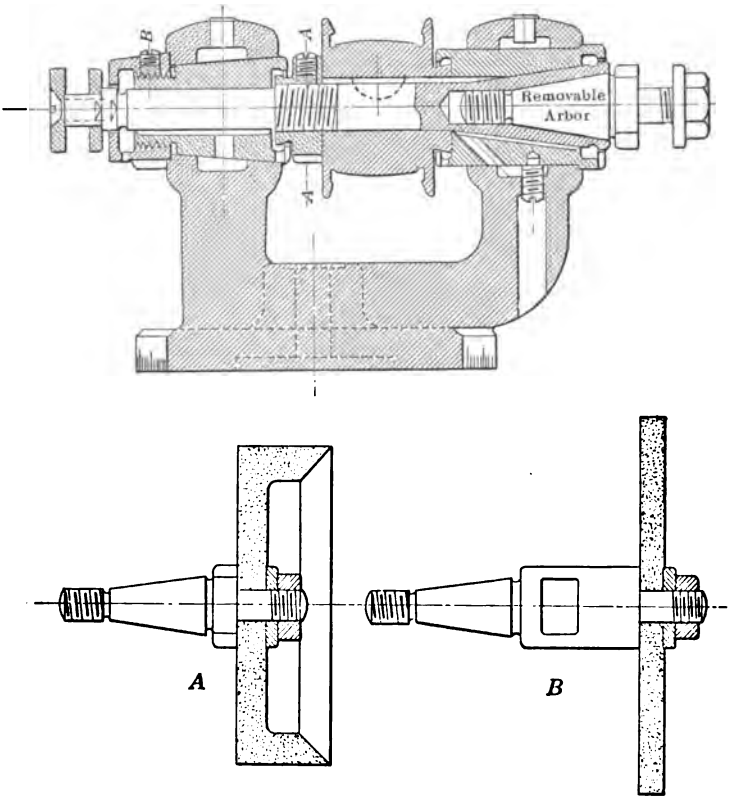


FIG. 108. INTERCHANGEABLE WHEEL ARBORS FOR LEBLOND-CUTTER GRINDER.

screws. By putting pieces of leather between the ring *B* and the wheel, there is no danger of cracking the wheel when tightening the ring. In replacing the mount on the face-plate *C* be sure that both face-plate and mount are clean and free from dirt. The inside of the wheel should be covered with beeswax. Most of the makers are now treating the wheels in this manner. If omitted, it should be supplied by the user, as it is a most important factor in guiding the inside stream of water. Be sure that the wheel band is securely fastened on the wheel before starting.

INTERCHANGEABLE WHEEL ARBORS FOR CUTTER GRINDER

The cutter grinder made by the R. K. LeBlond Machine Tool Company, is equipped with interchangeable wheel arbors as illustrated in Fig. 108. Style *A* is regularly used for mounting wheels on the spindle to make it unnecessary to true up the wheel each time it is changed. Style *B* is an extension arbor which is used for mounting wheels for surface grinding.

The section through the wheel head and spindle shows the manner in which the arbors are carried in the spindle.

DRESSING GRINDING WHEELS[1]

The difference between glazing and loading of a grinding wheel is not always clearly understood.

A loaded wheel is one whose face has particles of the metal being ground adhering to it—one in which the openings or pores of the wheel face have been filled up with metal, leaving no room for clearance. It is not necessary that all of the pores or openings between the cutting particles on the face of a wheel be filled up or loaded to prevent the wheel from cutting. The presence of a number of these pieces of metal on the face of a wheel prevents the wheel from cutting into the work and the loaded places will, of course, create heat.

A GLAZED WHEEL AND ITS EFFECTS IN GRINDING

A glazed wheel is one whose cutting particles have become dull or worn down even with the bond, the bond being so hard that it does not wear away fast enough to allow spaces between the cutting particles, or the cutting particles to escape when dulled. In a glazed wheel, the cutting particles and the bond at the extreme surface of the wheel are of the same radius.

It will be noted that in many places the space between the cutting particles is filled with bond and the corresponding spaces in the wheel on the left are open and will give room for clearance. Continued work with a wheel that glazes increases the smoothness of the wheel face and decreases the cutting.

A wheel will not load unless the bond is too hard or it is run at a speed very much too slow. The factors that cause loading are, therefore, hard bond and slow speed. Loading may indicate that the wheel is too hard or that it is running too slow, or both.

The factors that cause glazing are hard bond and high speed. Glazing may indicate that the wheel is too hard for the work, or it may be running too fast. A wheel of the right grain and grade may glaze if run too fast, or a wheel run at the right speed may glaze if it is too hard for the work. In short, a wheel loads when it is too hard or when it runs too slow, and a wheel glazes when it is too hard or runs too fast.

[1] The Norton Company.

One remedy for loading is to increase the speed. A remedy for glazing is to decrease the speed. If the speeds are right, use a softer wheel in either case.

Loading and glazing make excessive dressing necessary, and excessive dressing wears wheels faster than grinding. Were it possible to obtain an ideal wheel for each kind of work, theoretically dressing would not be necessary as the face of the wheel would automatically sharpen itself.

A WHEEL OUT OF TRUE SHOULD BE FREQUENTLY DRESSED

Whenever the work is of such a nature as to cause the wheel to run out of true, frequent dressing will save the wheel rather than waste it. For example, a wheel that ran out 1/32 in. after 1 hour's grinding ran out 1/8 in. after 2 hours, grinding. Had it been dressed after the first hour and again after the second hour, the amount wasted by dressing would have been 1/16 in., whereas after the wheel ran 2 hours it was necessary to dress off 1/8 in. or twice as much.

Wheels should be kept in perfect running condition, in order to give good results and a wheel should never be used until the operator is sure the wheel runs true.

We can never grind perfect work with an imperfect wheel, and the more perfect and smooth the wheel is the more perfect and smooth will the work be, particularly when making the light finishing cuts.

DRESSERS AND TRUING WHEELS

Dressers should always be kept handy for wheels for off-hand grinding but for truing wheels on plain, cylindrical and universal grinding machines, cutter and reamer grinders, etc., a diamond is necessary for good results.

Dressing is not truing, but sharpening the wheel, and a dresser should never be used on wheels that grind round work on centers. When truing a wheel for round grinding, the diamond should be held in a rigid tool post on the table of the machine. We cannot do good work with a wheel that has been trued "by hand." When a dresser is used, it should be moved in a straight line across the face of the wheel, with the heel of the dresser resting firmly against the edge of the work rest.

It may be well to state here that dressing is sharpening the wheel, and truing means to perfect the wheel—make a perfect cylinder of it, which is absolutely necessary if it is intended to grind a perfect cylinder with it.

WHEEL DRESSERS AND DIAMOND TOOLS

Several standard grinding wheel dressers are shown in Fig. 109. The dresser at *A*, is of the well-known Huntington pattern, with alternating sharp-tooth cutters and plain disks as indicated at *B*. These parts are loosely mounted

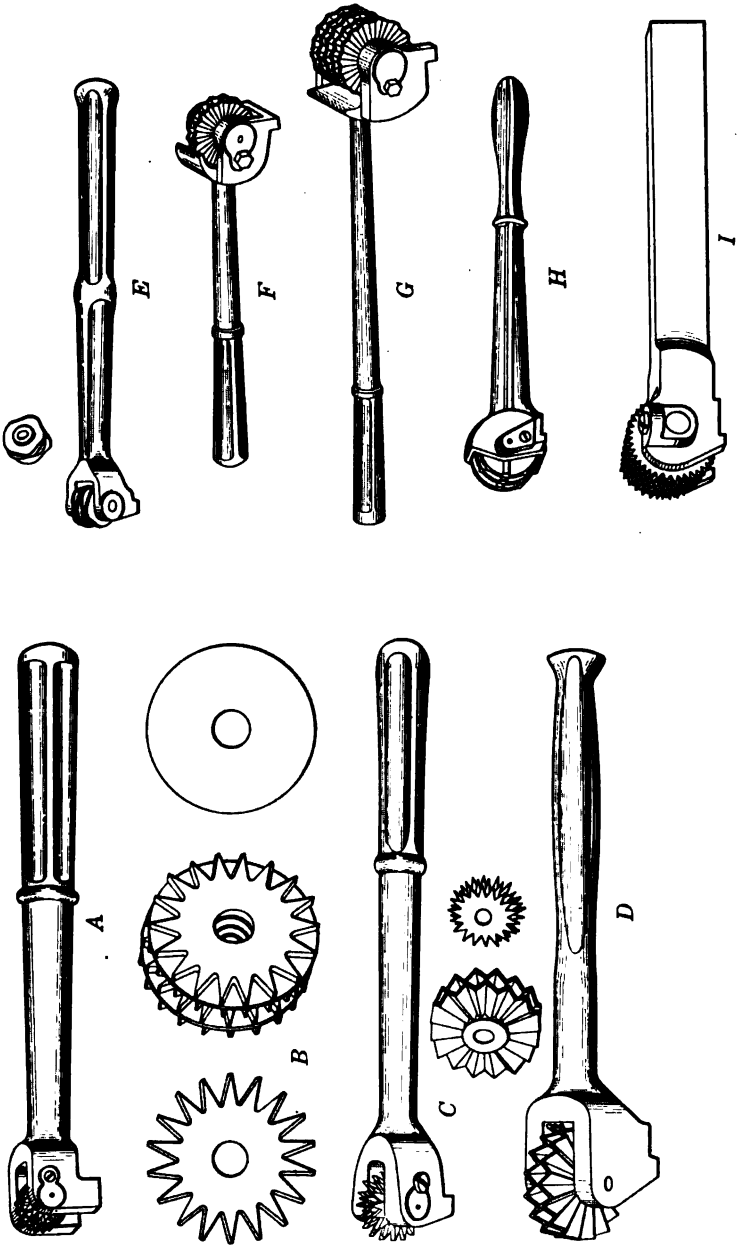


FIG. 109. WHEEL DRESSING TOOLS.

in the holder (which is about 12 in. long) so that they cut freely, at the same time the disks prevent excessive wear on the pointed cutters.

A dresser with a series of plain pointed-tooth cutters is shown at *C*, while *D* illustrates the corrugated type of dresser. The dresser *A* is recommended for use on the smaller and finer wheels, and the two at *C* and *D*, both 14 in. long, for large and coarse grit wheels.

The dresser with twisted cutters at *E*, is made by the Norton Company in two sizes, one for small, the other for large wheels. The Safety dressers shown

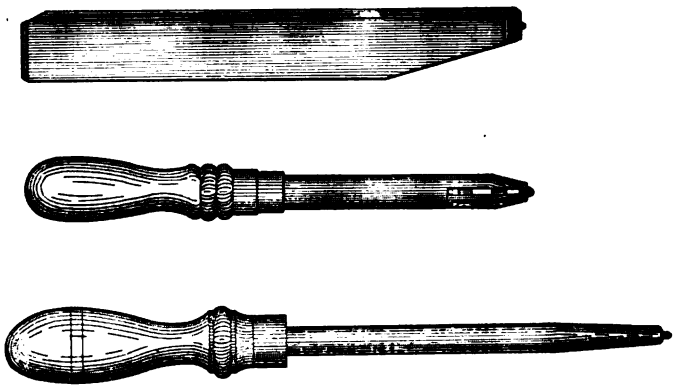


FIG. 110. DIAMONDS FOR TRUING WHEELS.

at *F* and *G*, are made by the Safety Emery Wheel Company and the larger of the two was designed for use with their plow grinding system on wheels 2 1/2 in. or more in width. The handle holds five corrugated cutters which are 3 in. in diameter and made from tough, white iron. The handle is long and the user is fully protected by the guard from any broken pieces of the cutters and from dust from the wheel.

Another dresser with a guard (the Wrigley) is shown at *H*. The lower dresser *I* is for use in the lathe.

Some hand and lathe diamond tools which are made in various forms are shown in Fig. 110. Various methods of setting diamonds and using them are shown in the pages that follow.

USING THE WHEEL DRESSERS

In using grinding wheel dressers set the rest firmly about level with the center of the wheel and far enough from it so that when the claws of the tool are hooked over its inner edge the points of the cutters will not quite touch the wheel when the tool is held level. Bring the cutters in contact with the wheel by firmly and gently raising the handle of the tool as the high and uneven places are cut down. In using the tool, pass or slide it slowly back and forth

against the wheel, using less pressure when cutting down the corners or turning a sharp bevel. If the wheel is glazed or slightly out of true, only touch it lightly, or the fast cutting of the tool will unnecessarily waste the wheel. Hold the tool in such a manner that the cutters will revolve with the wheel and in line with its motion. If fire flies, it is a sign that the wheel is grinding away the points of the cutters, because of their ruunning from want of oil, or an improper position of the tool.

THE USE OF DIAMONDS[1]

It is perhaps well to give the question of diamonds some little consideration here as they are sometimes a very expensive item. A diamond is a very essential part of a grinding machine's equipment for in its absence a good and highly finished grade of work is an impossibility. It is perhaps unnecessary to state that they should be the hardest rough stones procurable, and that the larger they are the cheaper they are in the end. With regard to their size: This is a known proportionate element in their price per carat, but a large stone allows of a more secure hold in its setting and so the danger of losing it is reduced. As a further precaution against this danger the diamond tool should always be held by mechanical means when using it except in cases which are unavoidable; this may be in cases where profile shapes have to be turned on the wheel face. An attempt to turn by hand a perfectly flat face on a wheel, which is necessary for finishing, must of a necessity end in failure, putting aside the risk of grinding away the setting.

There is often a somewhat pardonable reluctance to supply each separate machine in a grinding plant with a diamond, but it is not difficult to prove that it is a mistaken economical idea. If one diamond is allotted to two or more machine operators there is no one directly responsible for its care and it must naturally have the total wear of an adequate supply. Another point to consider is the loss of time incurred in chasing around for it by the man who wants to use it, and the not unusual chat with the workmate he finds in possession of it. As a preservation of the diamond a full stream of water should be run on it when in use and many light chips are preferable to a few heavy ones. The main thing to watch is that it does not get unduly heated, for this is disastrous to it. Where large quantities of material have to be moved from a wheel the ordinary wheel dresser may be employed to reduce the bulk of the stock and the diamond only used for finishing to shape.

SETTING THE DIAMONDS

Diamonds may be obtained ready fixed in suitable holders or the rough stones may be bought and set by any competent toolmaker. The illustrations show various methods by which they may be held securely and require but little explanation. At *A*, Fig. 111 is shown the method most commonly used,

[1] H. Darbyshire.

the diamond being either peened or brazed in position. One disadvantage of this method is that the diamond is apt to break with a chance blow of the peening chisel, or the heat from brazing will sometimes cause fractures; neither is it so easily reset when its point becomes dulled as are the other methods shown. *B* requires no explanation except that it is advisable to pack the diamond with shredded asbestos fiber to act as a cushion; this method allows of quick resetting. *C* consists of a small steel cap tapped out to fit the stock as shown. Enough shredded asbestos fiber is inserted between the diamond and stock to hold it

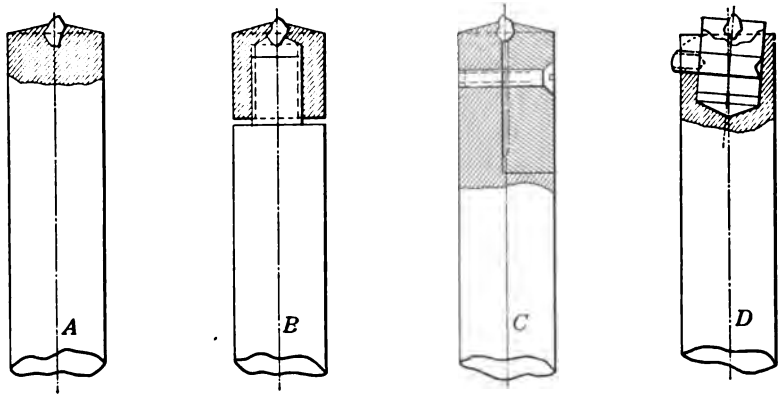


FIG. 111. METHODS OF SETTING DIAMONDS.

firmly in position. This method also allows of quick and safe resetting. The fourth method, *D*, is, we believe, covered by patent rights and its advantage can be seen at a glance; as the diamond wears, the small peg containing it can be revolved in the stock to present a new cutting edge and be so clamped in position. Diamonds should be kept fairly sharp and as their points wear off they should be reset to present their next best one. When worn quite round they can usually be sold to the diamond dealers who can find other markets for them. Don't let the diamond get too blunt or it will burnish the face of the wheel and so cause it to glaze and burn the work.

WHAT THE BLUNT DIAMOND DOES

A customer complained of wheels supplied him, contending that they were not duplicates of those previously used although labeled the same grit and grade. A visit to the works elicited the fact that the wheels would rough out alright but they could not finish with them as they did with the old ones, and they burnt and discolored the work and caused the fine chatter marks occasionally; the diamond used for truing the wheels was examined and found to be as rounded as a pea and resetting it with a cutting point projecting got over the difficulty.

A blunt diamond is an abomination and has caused endless and costly trouble both to wheelmakers and users. A diamond is a tool provided as a means of truing the wheel to shape or removing glaze and in a blunt condition will only aggravate the latter condition; it can only true the wheel when the spindle is in perfect running order and only attains this end by rolling and burnishing the grit of the wheel into anything but a cutting condition; while in this state it is a polishing wheel only and will engender unnecessary heat in any work on which it may be engaged.

TROUBLE WITH A POORLY FACED WHEEL

During a visit to a factory attention was drawn to a machine in which the operator was grinding the front journal of a turret-lathe spindle. The superintendent complained that the man had been engaged some 90 minutes in finishing this part and could not get it round within 0.0075 in., although the grit and grade of the wheel were quite suitable for the work. An examination of the wheel face raised a suspicion of the cause, which was found to lie in the bluntness of the diamond; the wheel was immediately trued up with a diamond which had a cutting edge and the journal was finished in a few minutes without any difficulty.

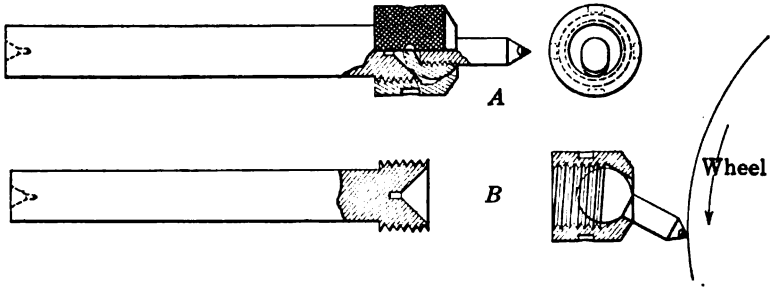


FIG. 112. DIAMOND TOOL AND HOLDER.

There are various ways of setting a diamond so that it can be readily turned when one edge is blunted. It is essential that it be kept sharp just as with any other cutting tool and this seems to be a point that is overlooked by many.

DIAMOND TOOL AND HOLDER

Still another form of diamond tool and holder is shown in Fig. 112. This was made by J. A. Phillips for use in the universal grinding machine when engaged in light-tool and gage work; a good sharp corner on a diamond is then a very desirable thing, and this tool seems to just fill the bill.

The tool consists of a diamond set in a piece of copper or steel, threaded at end to screw tightly into a ball that has been softened, drilled, tapped and rehardened.

The holder is in two parts; the shank and the nut, or cap as in Fig. 112.

A shows the assembled tool, partly in section.

B is a section of shank and nut with tool inclined in the direction the wheel is revolving.

The shank is a length of steel, reduced in diameter to within a short distance of the end which is threaded. This end is countersunk with a conical cutter of 90 degrees, after being drilled with a small drill to relieve the point of the cutter.

The nut, or cap is threaded to suit the shank. The thread must be so chosen that the core diameter will admit the nut passing easily over the ball, and the included angle of the faces that tighten on the ball is 60 degrees. The front of the nut is cut away at one point to permit setting the tool at an angle with the shank.

In use, the tool with newly set, sharp-pointed diamond, is set straight in the shank; the point then contacts with the wheel. When the point is worn off and a flat is formed, the sharp edges of the flat are brought into operation on the wheel by slacking the nut, and setting the tool at an angle with the shank by locating in the part of the nut cut away; then, as the edge is worn away, the tool is turned around in the nut, keeping the same angle with relation to the shank until all the edge of the flat is worn off, thus automatically producing a point again, when the tool is set straight to bring the new point into play, and the cycle of operations repeated.

When using with the tool at an incline, it is wise to see that the shank is set in the machine in such a manner that the tool points downward as in the sketch, the wheel has then no tendency to slacken the nut by vibration and drag the diamond down to its destruction.

A CLAW SETTING FOR THE DIAMOND

It is stated by T. Powell that users of the diamond for truing wheels on grinders, etc., will find the following method of setting a diamond has decided advantages over ordinary methods of riveting, soldering, etc., The sketch Fig. 113, shows the stock, size to suit requirements, or holder, tapered on the end and with a hole drilled in to hold the diamond quite freely; the piece is afterward slotted crosswise 1/32 in. to 1/16 in. wide, which can readily be done in the milling machine, or with a thin slotting file or saw. The diamond is then placed in position and the four "claws" pinched in to hold it, and the whole is brazed up together, using brass rod or strip, which must be free from grease and preferably cleaned in benzine; after brazing, surplus brass is cleaned away from around the sides of the stock and from the point of the diamond.

The advantages claimed and the simplicity of the thing will be readily seen, one thing in particular being the easy way of getting the exact point of the diamond, without fear of its shifting.

SETTING THE DIAMOND POINT ECCENTRIC

F. J. Hohnhorst recommends setting the diamond so that it is eccentric in the holder. He says:

"In truing the emery wheel, it is very important that the diamond be presented to the face of the wheel with a sharp point. To accomplish this, the diamond should be turned in the diamond tool holder on the machine after the emery wheel has been dressed several times; this will present a new and sharp point to the emery wheel.

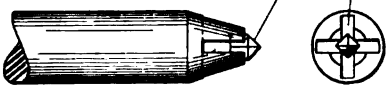


FIG. 113. CLAW SETTING FOR DIAMOND.

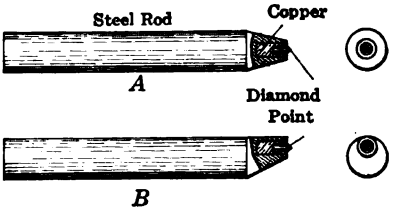


FIG. 114. SETTING THE DIAMOND POINT.

"In setting the diamond in the steel rod, it is usually found set in the center, as shown at *A*, Fig. 114. When the diamond has been turned several times, it becomes worn and flattened, because the diamond always remains central, and can only be turned around in the diamond tool holder on the grinder.

"At *B* is an improved way of setting the diamond; it is set eccentric. The improvement to the diamond can easily be seen, as this way of setting it enables the grinding-machine operator to turn the diamond centrally above center, or below center, thereby getting a wider range and more use of the diamond. Besides it does not have to be reset nearly so many times as when set as shown at *A*."

DIAMOND HOLDER WITH WATER CONNECTION

S. W. Field uses a diamond holder mounted as in Fig. 115, so that it comes below the center of the wheel and a new edge can be obtained on the diamond by revolving the holder in its socket.

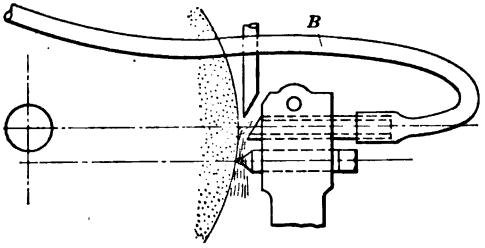


FIG. 115. TRUING WHEELS WITH DIAMOND BELOW CENTER.

In truing up wide wheels the ordinary supply of water is not suitable for keeping the diamond cool as it is usually conducted through a pipe which is fastened to the splash guard and does not follow the diamond. Fig. 115 also shows a way out of this difficulty; a rubber tube *B* is connected to the ordinary

supply pipe and water is fed onto the wheel, through this, immediately above the diamond, thus keeping that important tool always in a stream of water.

SIMPLE DEVICE FOR SHAPING A GRINDING WHEEL

It is often necessary, in grinding, to use an emery wheel having a true concave or convex edge or periphery.

A few years ago an *American Machinist* contributor was employed by a firm that manufactured bicycle chains in large quantities, the heads of the rivets being "spun" on by a pair of small rollers *A*, Fig. 116. When two of the rollers were placed side by side, as at *B*, the corners combined to make as perfect a semicircle as possible. When through use the rollers became worn or "pitted"

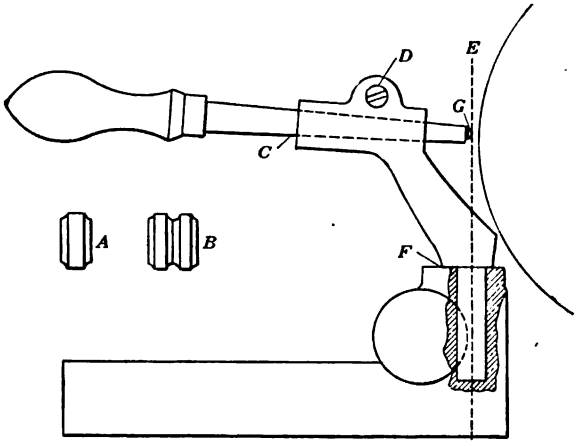


FIG. 116. DEVICE FOR SHAPING EMERY WHEEL.

they were reground, and were thus used over several times. For the sake of economy and ease of adjustment, two or three dozen rolls or "spinners" would be ground at one time and accurately enough so the face of one roller would mate perfectly with the face of any other in the same lot.

A forging was made and drilled through at *C*, a binding screw being added at *D*, which held and clamped the diamond turning tool at any distance from the center line *E;* the lower end of the forging was turned with a shoulder at *F*, and made a neat working fit when inserted in one of the tooth rest holders supplied with the grinding machine.

If a roller for forming a rivet head with a radius of, say, 1/8 in. was required, the diamond truing tool was clamped in position with the point *G* 1/8 in. back of the center line *E;* the tool was then fed against the wheel by the cross feed, and the handle *H* swung slowly round by hand, turning the edge of the emery wheel to the desired radius.

With this tool-holder a wheel could be produced with any radius from 0 to 1

in. which was very handy when grinding out the flutes of taps, "touching up" milling cutters, forming tools and odd jobs.

By setting the diamond "by" the center line, a wheel with a concave edge was produced.

DRESSING SURFACE-GRINDER WHEELS

It is sometmies necessary to dress surface-grinder wheels accurately to a given angle, to form angles on work, not accessible for grinding by the usual cross traverse. Any angle from parallel with the axis, to 90 degrees with the axis, can readily be dressed, by tilting the swivel vise (Fig. 117) to the desired angle, and clamping the diamond holder to the sliding jaw, using the traverse of this jaw to form the angle.

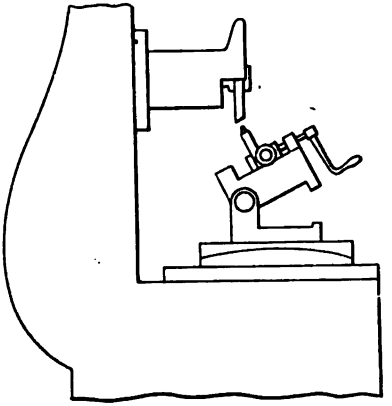


FIG. 117. DRESSING SURFACE-GRINDER WHEELS.

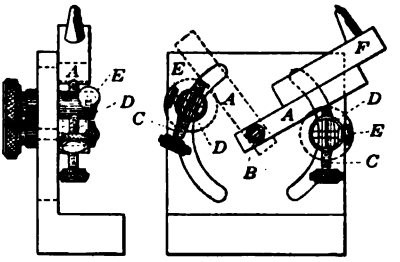


FIG. 118. THE DEVICE.

The diamond holder is clamped by means of a screw, with a large flange, tapped into the sliding jaw as shown. It will be seen that the diamond point must be centered with the wheel, or in other words must operate on the wheel at its lowest extremity to produce a true angle; the vise is covered with a cloth when dressing to keep the dust from the working parts.

ANOTHER DEVICE FOR TRUING SURFACE-GRINDER WHEELS

Another device for this same purpose which has been in successful use in for some time is shown in Fig. 118.

The device is used on a magnetic chuck, but it can be clamped to the table as well.

The bar *A* is a piece of hardened and ground tool steel, and swings on the stud *B*. It is adjusted to the correct angle by the screws *C C*, these being held tightly in place in the split studs *D D* by the small thumb screws *E E*. The diamond is mounted on the square piece of steel *F*, which slides in the corner made by the bar *A* and the back of the fixture; *F* is pushed back and forth by

hand. The top of the fixture being ground, it forms a convenient surface on which to set the protractor when setting the bar *A* to accurate angles.

As the bar swings on a stud and the location is held by the screws *C C*, two angles on the same wheel may be dressed and redressed without changing the setting.

As the diamond is not clamped to the fixture, it can be used between times for free-hand dressing of the wheel, rounding corners, etc.

As the diamond can be used at the extreme edge of the fixture on either side, any angle can be dressed on the inside of the wheel.

As there is neither a closely fitted slide nor oil, it has not been necessary to protect the fixture in any way.

The above fixture has been in use for several years in grinding many different shapes of vertical forming tools. It has not been repaired in any way and has given perfect satisfaction.

RIGHT AND WRONG WAY OF TRUING WHEELS

A. B. Schliefer, referring to the truing of wheels on the surface grinder, says: "Many people true the wheel of a surface grinder as shown at *A*, Fig. 119. If the spindle

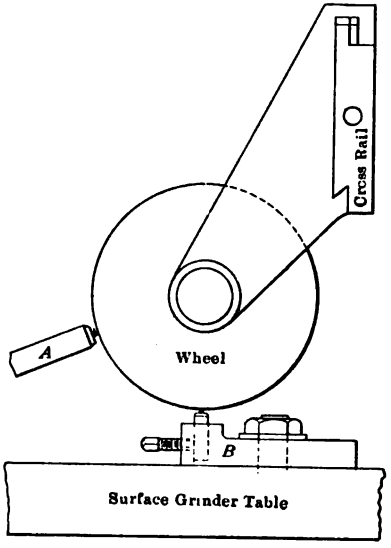


FIG. 119. RIGHT AND WRONG METHODS OF TRUING SURFACE-GRINDER WHEELS.

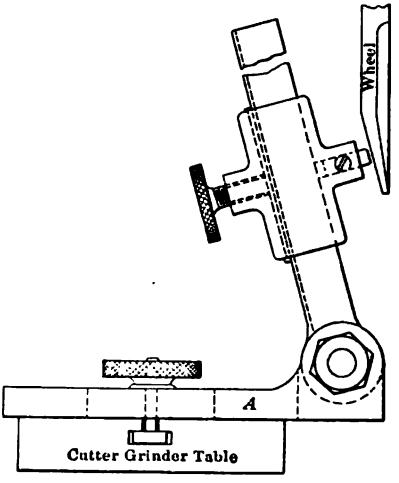


FIG. 120. WHEEL TRUING DEVICE.

should not be quite parallel with the cross-slide the wheel does not have a face parallel with the work. This, of course, causes unsightly feed lines to show up on the ground surface; then again the truing fixture must be affixed and removed at each truing operation. The method at *B* is submitted as being a far better one as it insures accuracy and gives much less trouble. The diamond is held in a small plate which is drilled for a holding-down bolt; whatever the piece of work to be ground, the diamond is mounted on packings to a hight just below that of the work surface at the back of the work. When it is necessary to true the

wheel, the table is run forward until the diamond is just below the wheel center; the wheel may be then fed down to the diamond point and traversed across it."

He also uses a fixture like Fig. 120 for truing the beveled side of saucer wheels. It is cheaply made and will insure a clean, true cutting face on the wheel; the main thing is to have a good sharp diamond so that it will actually "cut" and not rub. Referring to Fig. 120, *A* is a piece of cast iron machined to fit the diamond holder pillar and slotted to admit a holding-down bolt. It will be seen that the pillar carrying the diamond holder can be swung over to any angle and the diamond is fed over the wheel-face by hand. A locking screw is provided for locking the diamond in position when this is desirable.

SPEED TABLES, RULES FOR SURFACE SPEEDS, ETC.

The table below gives the number of revolutions per minute at which grinding wheels of diameters ranging from 1 to 60 in. must be operated to secure peripheral velocities of 4000, 5000, 5500 and 6000 ft. per minute.

Diameter wheel	Rev. per minute for surface speed of 4000 ft.	Rev. per minute for surface speed of 5000 ft.	Rev. per minute for surface speed of 5500 ft.	Rev. per minute for surface speed of 6000 ft.
1 in.	15,279	19,099	21,000	22,918
2 in.	7,639	9,549	10,500	11,459
3 in.	5,093	6,366	7,350	7,639
4 in.	3,820	4,775	5,250	5,730
5 in.	3,056	3,820	4,200	4,584
6 in.	2,546	3,183	3,500	3,820
7 in.	2,183	2,728	3,000	3,274
8 in.	1,910	2,387	2,600	2,865
10 in.	1,528	1,910	2,100	2,292
12 in.	1,273	1,592	1,750	1,910
14 in.	1,091	1,364	1,500	1,637
16 in.	955	1,194	1,300	1,432
18 in.	849	1,061	1,150	1,273
20 in.	764	955	1,050	1,146
22 in.	694	868	950	1,042
24 in.	637	796	875	955
26 in.	586	733	800	879
28 in.	546	683	750	819
30 in.	509	637	700	764
32 in.	477	596	650	716
34 in.	449	561	620	674
36 in.	424	531	580	637
38 in.	402	503	550	603
40 in.	382	478	525	573
42 in.	364	455	500	546
44 in.	347	434	475	521
46 in.	332	415	455	498
48 in.	318	397	440	477
50 in.	306	383	420	459
52 in.	294	369	405	441
54 in.	283	354	390	425
56 in.	273	341	375	410
58 in.	264	330	360	396
60 in.	255	319	350	383

TABLE 25.—GRINDING WHEEL SPEEDS

The exact speed at which any specified wheel should be run depends upon several conditions, such as the type of machine, character of work and wheel, quality of finish desired and various other factors referred to at other places in this book. Wheels are ordinarily run in practice from about 4000 to 6000 ft. per minute, though in some cases a speed as high as 7,500 ft. has been employed. An average speed recommended by most wheel makers is 5000 ft. To llow an ample margin of safety it is recommended that wheel speeds should not exceed 6000 ft. per minute.

CHART FOR GRINDING AND POLISHING WHEELS

The accompanying chart, Fig. 121, prepared by the Diamond Machine Company, covers speeds for water tool grinder wheels; dry grinder wheels;

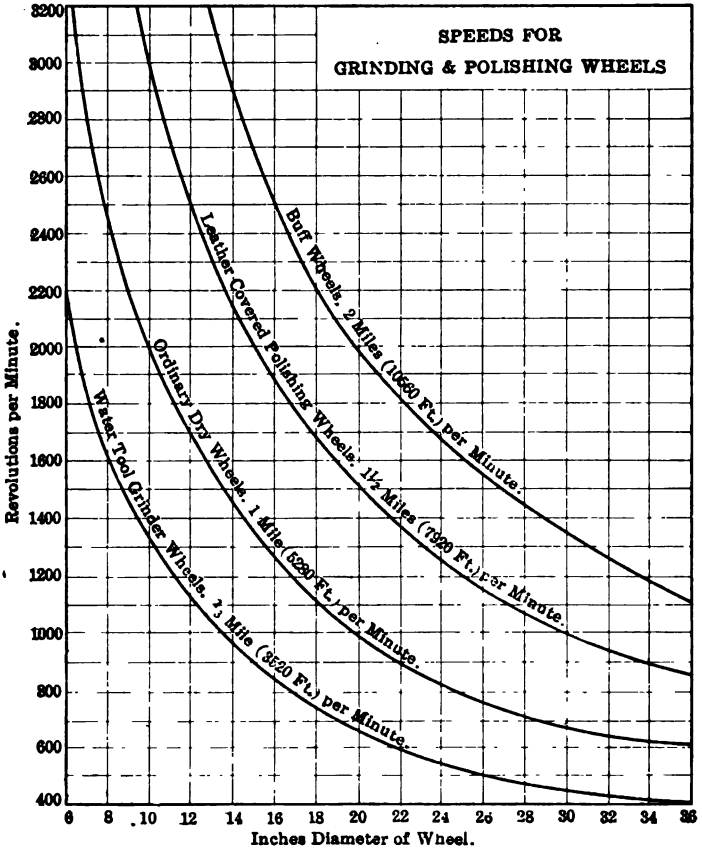


FIG. 121. CHART FOR APPROXIMATE SPEEDS OF EMERY AND POLISHING WHEELS.

leather-covered polishing wheels, and buff wheels. It is based on a speed of about a mile a minute for ordinary dry grinder wheels, and a speed for water

tool grinders of two-thirds that for dry grinders. The speed curves for leather-covered polishing wheels and buff wheels are based on speeds one and one-half and two times the velocities for dry grinder wheels. To determine the number of revolutions that a wheel in any of these classes should be run to give the corresponding peripheral speed, it is only necessary to trace a vertical line from the wheel diameter to the proper curve and from the point of intersection run a horizontal line to the scale of revolutions on the left of the chart.

RULES FOR OBTAINING SURFACE SPEEDS OF WHEELS

The table of circumferences below will be of service in connection with the finding of surface speeds and spindle revolutions per minute.

Diam. of wheel in inches	Circum. of wheel in feet	Diam. of wheel in inches	Circum. of wheel in feet	Diam. of wheel in inches	Circum. of wheel in feet
1	.262	25	6.546	49	12.828
2	.524	26	6.807	50	13.090
3	.785	27	7.069	51	13.352
4	1.047	28	7.330	52	13.613
5	1.309	29	7.592	53	13.875
6	1.571	30	7.854	54	14.137
7	1.833	31	8.116	55	14.499
8	2.094	32	8.377	56	14.661
9	2.356	33	8.639	57	14.923
10	2.618	34	8.901	58	15.184
11	2.880	35	9.163	59	15.446
12	3.142	36	9.425	60	15.708
13	3.403	37	9.687	61	15.970
14	3.665	38	9.948	62	16.232
15	3.927	39	10.210	63	16.493
16	4.189	40	10.472	64	16.755
17	4.451	41	10.734	65	17.017
18	4.712	42	10.996	66	17.279
19	4.974	43	11.257	67	17.541
20	5.236	44	11.519	68	17.802
21	5.498	45	11.781	69	18.064
22	5.760	46	12.043	70	18.326
23	6.021	47	12.305	71	18.588
24	6.283	48	12.566	72	18.850

TABLE 26.—CIRCUMFERENCES OF GRINDING WHEELS

Thus, to find the surface speed of a wheel in feet per minute:

Rule.—Multiply the circumference as obtained from the table, by the number of revolutions per minute.

Example.—A wheel 18 in. diameter makes 1060 r. p. m. What is the surface speed, in feet, per minute?

$$4.712 \times 1060 = 5000 \text{ ft. surface speed.}$$

When the surface speed and wheel diameter are given, to find the number of revolutions of the wheel spindle:

Rule.—Divide the surface speed in feet per minute by the circumference.

Example.—A wheel 24 in. diameter is to be run at 6000 ft. surface speed per minute. How many revolutions should the wheel make?

$6000 \div 6.283 = 962$, number of revolutions per minute the wheel should make.

RULES FOR FINDING SPEEDS AND DIAMETERS OF PULLEYS

The proposed speed of the grinding spindle being given, to find the proper speed of the countershaft:

Rule.—Multiply the number of revolutions per minute of the grinding spindle by the diameter of its pulley, and divide the product by the diameter of the driving pulley on the countershaft.

Example.—The driving pulley on the countershaft is 18 in. diameter, the pulley on the grinding spindle is 10 in. diameter and makes 1000 revolutions per minute. How many revolutions per minute does the countershaft run?

$$\frac{1000 \times 10}{18} = 555 \text{ r. p. m.}$$

The speed of the countershaft being given, to find the diameter of the pulley to drive the grinding spindle.

Rule.—Multiply the number of revolutions per minute of the grinding spindle by the diameter of its pulley, and divide the product by the number of revolutions per minute of the countershaft.

Example.—The pulley on the wheel spindle is 8 1/2 in. in diameter and should make 1000 r. p. m. The countershaft runs at a speed of 500 r. p. m. How large should the driving pulley on the countershaft be?

$$\frac{1000 \times 8\ 1/2}{500} = 17 \text{ in. diameter of driving pulley countershaft.}$$

The proposed speed of the countershaft being given, to find the diameter of the pulley for the lineshaft:

Rule.—Multiply the number of revolutions per minute of the countershaft by the diameter of the tight and loose pulleys and divide the product by the number of revolutions per minute of the lineshaft.

Example.—A lineshaft running 150 r. p. m. is to drive a countershaft 450 r. p. m. The driven pulley on the countershaft is 9 in. in diameter. What diameter should the driving pulley on the lineshaft be?

$$\frac{9 \times 450}{150} = 27 \text{ in. diameter of pulley on lineshaft.}$$

CHAPTER VIII

SAFEGUARDS IN THE GRINDING DEPARTMENT

In the Chapter on Mounting and Dressing Grinding Wheels, correct and incorrect methods of mounting wheels on spindles are illustrated, and various types of flanges shown for promoting safety in operation. The reader is referred to that chapter for details of this character and for particulars as to wheel speeds, sizes of spindles recommended, and other data directly related to the subject of mounting wheels and keeping them in proper condition.

The whole subject of safeguards in grinding operations is of such importance that it has been deemed advisable to devote this special chapter to it, illustrating various devices and methods for preventing accident and guarding against injury to life and health. It has also seemed desirable to have this chapter follow immediately after the one on mounting and dressing wheels, owing to the immediate relationship between correct wheel mounting practice and safety in grinding operations. This arrangement it is felt may prove a feature of convenience to the reader.

In the first place it may be well to repeat a few suggestions made originally by well-known wheel manufacturers, and which if generally adopted ought to go a long way toward the elimination of wheel accidents.

It should be noted, in this connection, that very few wheels of standard makes are liable to break from defects due to manufacture; the improvements in wheelmaking processes and the severe tests to which the product is subjected make it seem unlikely that inherently defective wheels to any appreciable number ever find their way into service. But the abuse and misuse to which various kinds of wheels are subjected in operation gives rise to a certain degree of wonderment that accidents peculiar to grinding operations do not occur much more frequently than is actually the case.

A FEW GENERAL SUGGESTIONS

Handle all wheels with the greatest care in unpacking, storing, delivering, etc. Wheels are frequently cracked by rough usage before they are ever placed on the grinding machine. The man in charge of the storeroom should inspect each wheel before giving it out to the workman.

Wheels should be stored in a dry place.

A wheel used in wet grinding should not be left overnight partly immersed in water.

Use a rigid machine with well proportioned spindle and bearings.

Keep the bearings well oiled to avoid possibility of heating the spindle and bursting the wheel through expansion of its bushing.

Never crowd a wheel on the spindle; the bushing should be about 0.005 in. over-size, to slide nicely onto the spindle and squarely against the inside flange.

Never mount a wheel without flanges which are properly relieved and of suitable proportions. For details of flanges and methods of mounting various types of wheels see the preceding chapter.

Do not screw up the nut too tight; it should be set up only enough so that the flanges hold the wheel firmly.

Keep all rests adjusted close to the wheel so that work cannot be caught.

Avoid heavy pressure of the work on the wheel when grinding.

Keep the wheel true by dressing frequently.

If a wheel vibrates, there is something wrong. It should be trued up and the boxes should be rebabbitted after the journals are trued up.

Never hack a wheel; it is unnecessary and dangerous.

Use wheel guards wherever possible.

THE APPLICATION OF HOODS TO WHEELS

Modern machines for cylindrical and surface grinding are equipped with hoods that enclose the major portion of the wheel and which in case of accident would stop the broken wheel fragments and prevent injury to the operator.

FIG. 122. PROTECTION HOOD USED ON NORTON PLAIN GRINDING MACHINE.

Such a hood is shown in Fig. 122. In fact, practically all machines doing wet grinding including tool grinders, drill grinders, knife grinders, etc., require some form of shield to control the water of flying away from the surface of the

wheel, and most of these machines are therefore so well hooded as to make injury from a broken wheel quite unlikely.

But most dry grinders on the other hand, such as are used for "off-hand"

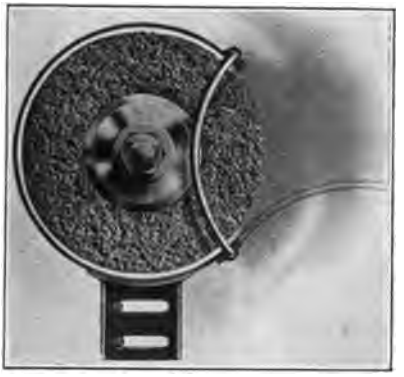


FIG. 123. PROTECTION HOOD FOR GRINDER WHEEL.

FIG. 124. PROTECTION HOOD FOR GRINDER WHEEL.

grinding of castings, steel strips, drop forgings, and an endless variety of other work along these lines, are still operated without hoods over the wheels and this class of machinery is only too liable to be run under conditions which sooner of

FIG. 125. NORTON GRINDING WHEEL STAND, FLOOR TYPE, EQUIPPED WITH PROTECTION HOODS.

later must lead to accident. For this reason it is important that so far as possible such machinery should be fitted with wheel guards, and in many cases where it has been deemed impracticable to put these on, reconsideration of the problem

will reveal the fact that suitable hoods actually can be applied with no great difficulty.

There is undoubtedly a strong tendency for workmen at an unhooded wheel to grind castings and such work at the front, top, back and both sides of the wheel at some time during the course of the day, particularly if the piece in hand does not from sheer weight and size make dependence upon the wheel rest obligatory. But it will be found that when the wheel is hooded the somewhat restricted area of wheel surface available will answer all legitimate purposes except in the cases of unusually large or awkward shaped castings. And these after all are not the kind commonly handled on grinders of this kind in the majority of shops.

A type of hood made by the Norton Company is illustrated by Figs. 123 and 124. It is stated that this form of hood has been in use 15 years and the manufacturers know of no operator of a grinder equipped with one of them who has been seriously injured by a broken wheel. In Fig. 125 a Norton grinding wheel stand, floor type, is shown equipped with a protection hood on each wheel.

OTHER WHEEL HOODS

A pamphlet issued by the above company on "Safety as Applied to Grinding Wheels" has already been referred to in the chapter on Mounting and Dressing Wheels. An important part of this interesting pamphlet relates to

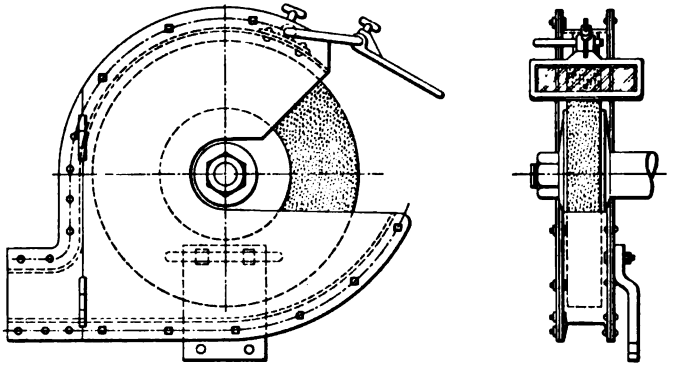


FIG. 126. RIVETED STEEL HOOD, WITH EXHAUST CONNECTION AND GLASS SHIELD FOR THE PROTECTION OF OPERATOR'S EYES.

the use of wheel hoods and through the courtesy of the Norton Company we are enabled to reproduce here a number of typical hood applications as therein illustrated.

Figure 126 represents a riveted steel hood with exhaust connection and glass shield for protecting the operator's eyes; Fig. 127 is a flexible, adjustable link, guard; Fig. 128, a pressed steel hood with a glass shield. The open side

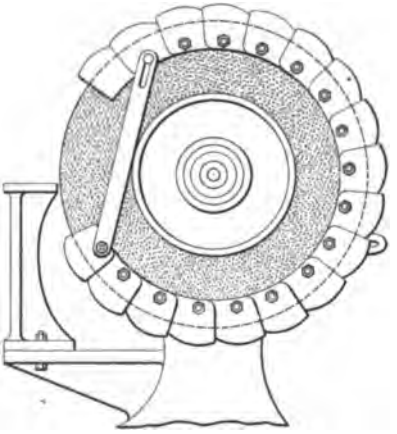


FIG. 127. FLEXIBLE, ADJUSTABLE LINK GUARD.

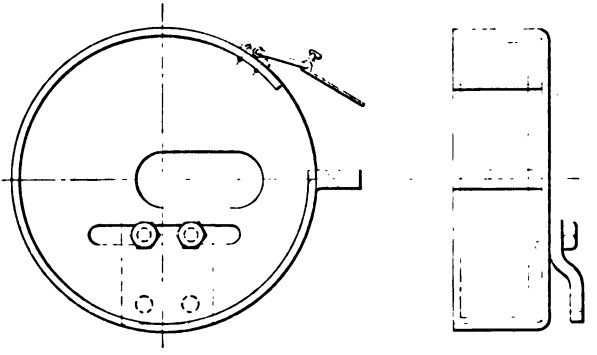


FIG. 128. PRESSED STEEL HOOD, WITH GLASS SHIELD.

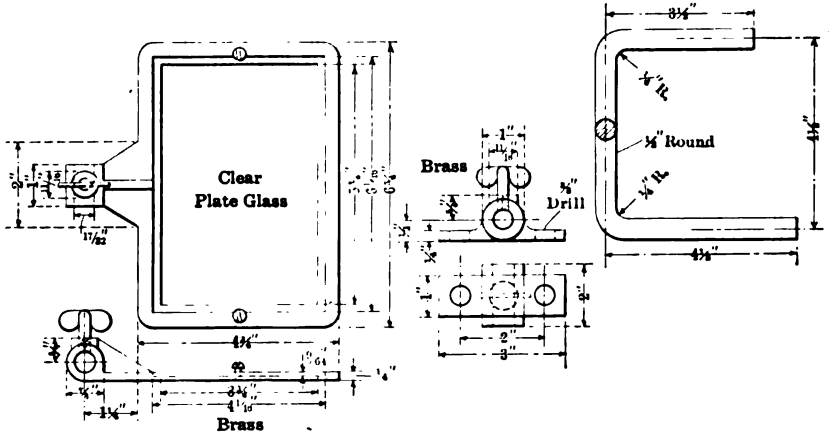


FIG. 129. GLASS SHIELD FOR GRINDING WHEEL.

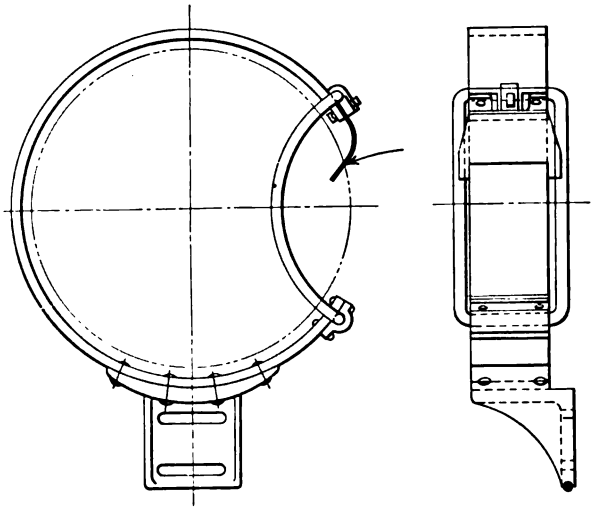


FIG. 130. PROTECTION HOOD AND LEATHER SPARK BRUSH.

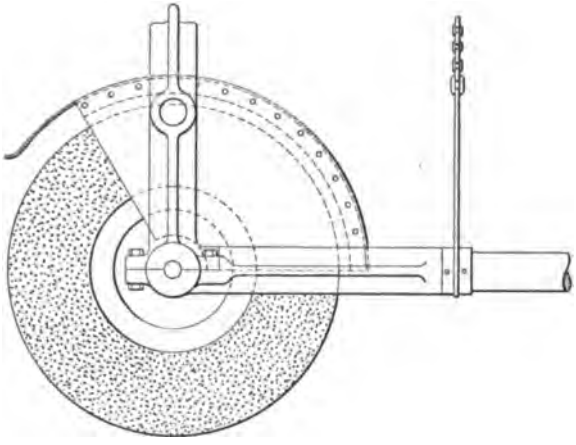


FIG. 131. APPLICATION OF PROTECTION HOOD TO SWING FRAME GRINDER.

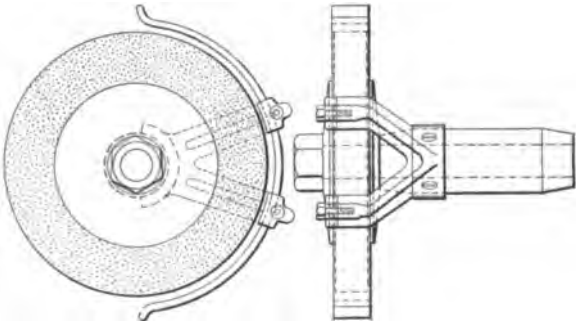


FIG. 132. HOOD APPLIED TO FLEXIBLE SHAFT.

may of course be covered and an exhaust connection applied if desired. The glass shield in this guard and in the one in Fig. 126, are of clear plate glass and afford protection to the operator's eyes when he is grinding fine work and it is necessary for him to work close up to the wheel. A shield of this kind may be applied by anybody to his own machines. Details are given in the print reproduced in Fig. 129.

Another type of guard for the eyes is shown on the hood in Fig. 130. This guard consists of a leather spark brush which is merely a flap of leather attached to the hood and so adjusted as to interrupt sparks and dust. Goggles are also used extensively around the grinder department, and many shops keep these in the tool room for use by anyone who has work to do at the wheel.

Figure 131 illustrates a hood on a swing grinder frame, and Fig. 132 shows the application to a wheel driven by a flexible shaft.

SOME GERMAN GUARDS

The wheel guard shown in Figs. 133 to 136 inclusive was illustrated some little time ago in the *American Machinist* and is from the German firm of Naxos-

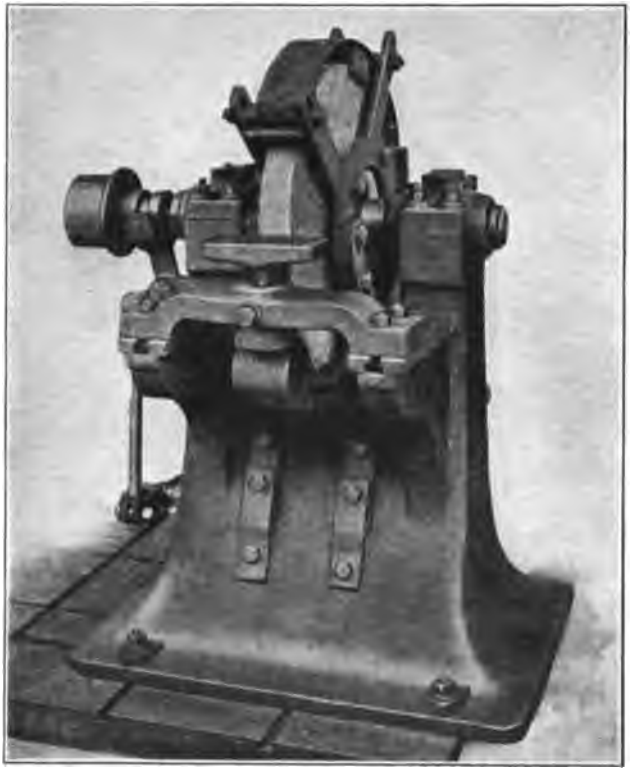


FIG. 133. GERMAN WHEEL GUARD.

Union, Frankfurt a.M. It consists essentially of a steel band that surrounds the wheel. At intervals there are channel-shaped pieces fastened to the inner side of this band and intended to project along the sides of the wheel and thus catch it in case it should burst. Provision is made for adjusting this band, within limits, to the size of the wheel. At the rear of the grinder is arranged a heavy weight to be tripped by the steel band when the wheel bursts. The drop-

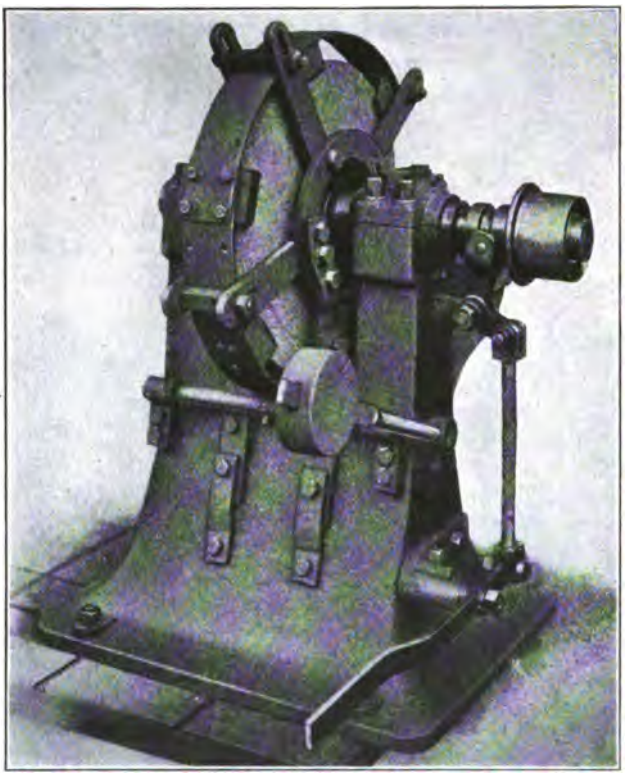


FIG. 134. GERMAN WHEEL GUARD.

ping of this weight brings it in contact with a lever, situated at the back of the machine near the base. This is connected through suitable mechanism with a clutch on the pulley shaft, and by this means the machine is stopped when the weight drops. Figures 133 and 134 show two views of the machine with the device in place. Figures 135 and 136 show the same device surrounding a broken emery wheel.

This wheel was run in a test for 8 minutes at a speed of 1260 revolutions, the equivalent of a circumferential speed of 39.56 meters per second, or say, 7250 ft.

per minute. During this interval the wheel was run entirely free. During the next 7 minutes it received 17 heavy blows on the side. These caused the wheel to burst into three pieces, as shown in the illustrations which bring out clearly the way in which the pieces of the broken wheel were held by the steel band.

Another German wheel guard is shown by Figs. 137 and 138. This form of guard is made up of corrugated sheet steel 1 1/2 mm. in thickness, several

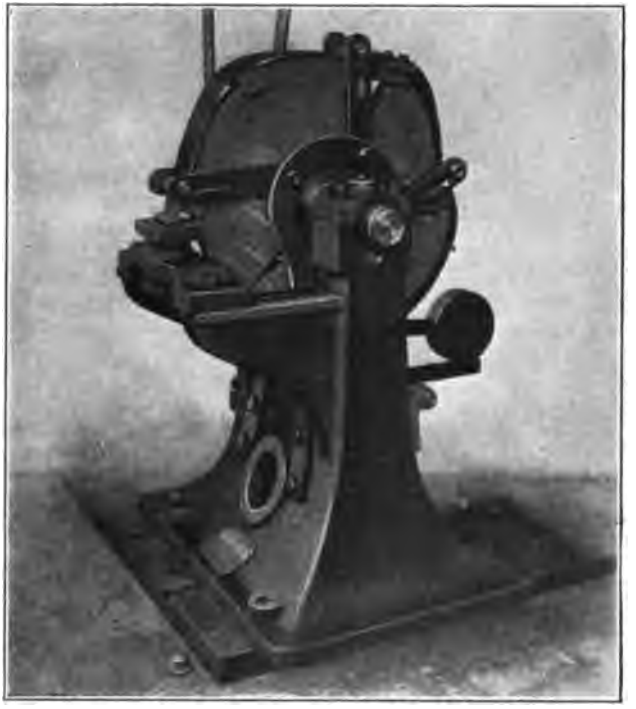


FIG. 135. A GERMAN WHEEL GUARD THAT CAUGHT A BURSTING WHEEL.

bands being held together by cross-bars or framework bolted together in such a manner as to form an elastic guard which is said to be effective in gripping and holding the parts of a broken emery wheel and keeping them from flying.

With this flexible guard the wheels tested ranged from 400 mm. to 700 mm. in diameter with speeds varying from 680 to 1650 r. p. m.

This form of elastic emery-wheel guard was designed and constructed at Hannover-Hinholz by the Vereinigte Schmirgel- Und Maschinen-Fabriken.

LIMITING THE SPEEDS OF WHEELS

The subject of wheel speeds has already been discussed in Chapter VII, and it is there pointed out that the peripheral speed of a wheel may be main-

tained as it wears away in service, by means of a cone pulley on the spindle or by changing to a smaller size of machine with a faster running spindle. In the latter case where there are two or three grinders operated at different speeds

FIG. 136. A GERMAN WHEEL GUARD THAT CAUGHT A BURSTING WHEEL.

FIG. 137. SPRINGING GUARD INTO POSITION FOR BOLTING TO FRAME

there is only one pulley on the spindle and the danger of running the machine at the wrong speed is eliminated. At the same time it is essential that means be provided to prevent wheels over a fixed diameter from being mounted.

A safety stop which makes it impossible to mount an over-size wheel on the grinder spindle is shown in Fig. 139, this illustration and Figs. 140, 141 and 142 being reproduced from the pamphlet referred to above on "Safety as Applied to

FIG. 138. WHEEL PROVIDED WITH ELASTIC GUARD.

Grinding Wheels." In this case the safety stops are shown as applied to a two-speed machine, the stops being so positioned that a wheel too large for safe operation at the fastest speed of the spindle cannot possibly be mounted.

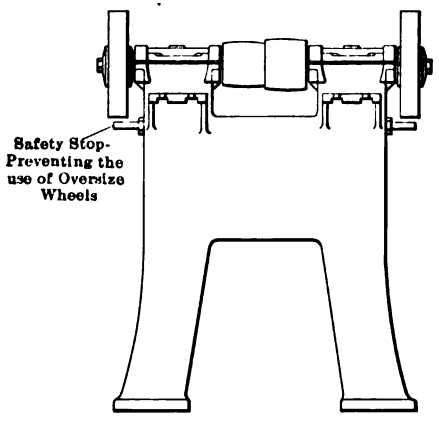


FIG. 139. DEVICE TO PREVENT USE OF WHEELS ABOVE A CERTAIN SIZE.

Another method of limiting the speed of the wheel is shown in Fig. 140. In this arrangement a rod *A* encloses the belt at the back of the pulley. When the belt is on the small pulley, a wheel large enough to give a dangerous surface speed cannot be mounted, owing to the interference of rod *A* at *a* and *B* at *b*.

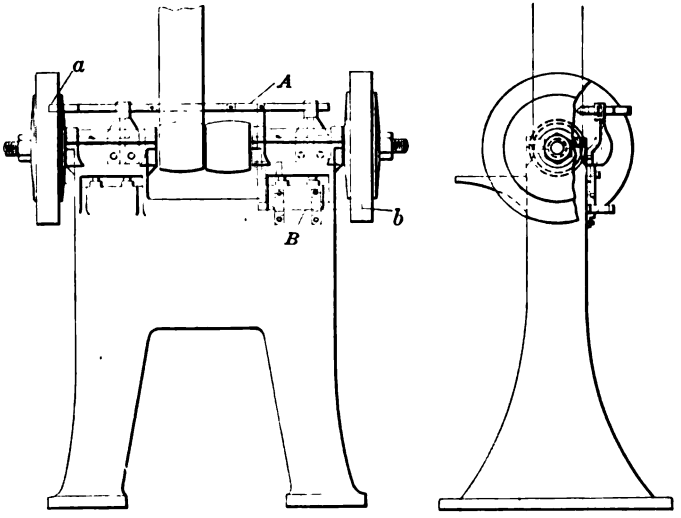


FIG. 140. DEVICE FOR LIMITING SPEED OF GRINDING WHEELS.

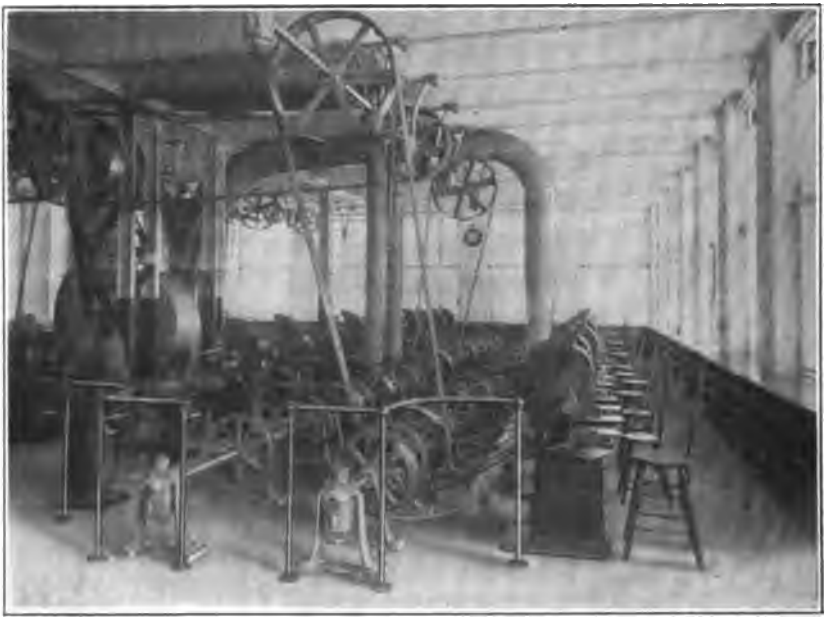


FIG. 141. A POLISHING ROOM WITH COMPLETE DUST SYSTEM.

Before the wheel can be mounted the belt must be shifted to the slow speed pulley. When this is done, rods *A* and *B* slide back clear of the sides of the wheel.

Speed tables and rules for finding surface speeds are given on page 171, Chapter VII. The tables give the number of revolutions per minute at which wheels from 1 to 60 in. diameter are driven to obtain surface speeds of

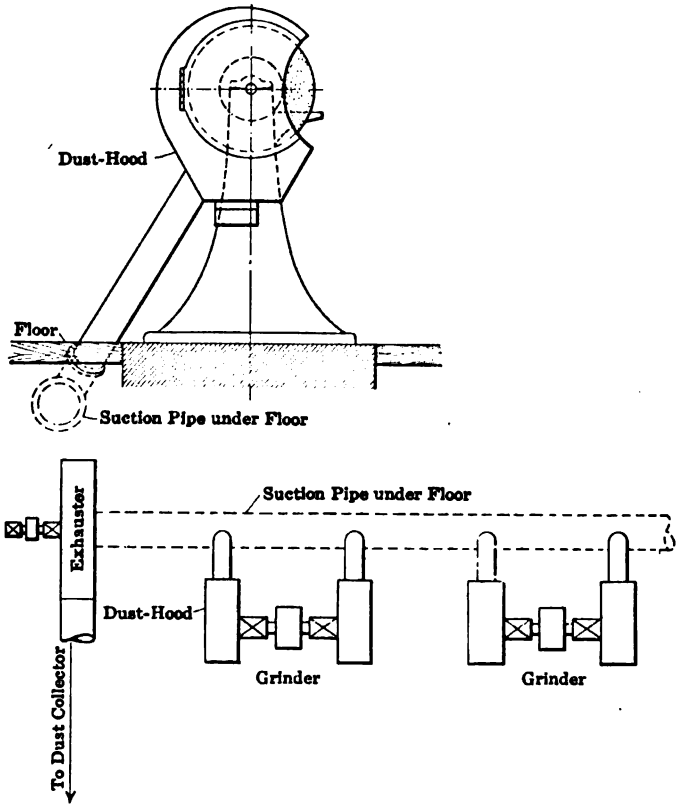


FIG. 142. PRACTICAL DUST SYSTEM.

4000, 5000, 5500 and 6000 ft. per minute. A table of circumference is also included at page 173, which will be found useful in connection with the figuring of surface speeds and spindle revolutions per minute.

OTHER SUGGESTIONS

Each machine should be marked with the number of revolutions and the size of wheel to be run upon it. In some shops a placard is hung over each machine giving the machine number, number of spindle revolutions at which it is to be run, the diameter of the wheel in inches, and the diameter at which it is to

be taken off. It also bears instructions that the foreman is to be notified when the wheel requires dressing.

All grinding machines in the department should be examined every morning by the foreman or his assistant to determine if the bearings are properly adjusted and oiled and the wheels in good condition. The man in charge should inspect each wheel carefully before it is placed on the arbor.

Competent men should be appointed to mount and true the wheels, adjust the rests and regulate the speeds.

DUST SYSTEMS

It is highly important that grinding and polishing rooms should be properly ventilated and well lighted and that the machines should be connected to an efficient dust system, not only for the preservation of the health of the workmen, but also to prevent unnecessary wear and tear on the machinery and belts.

Figure 141 illustrates a modern polishing department, with good dust system in the plant of the Brown & Sharpe Manufacturing Company, Providence, R. I.

Figure 142 shows the system in use at the Norton Company's plants. The main pipe it will be noticed is put in the ground.

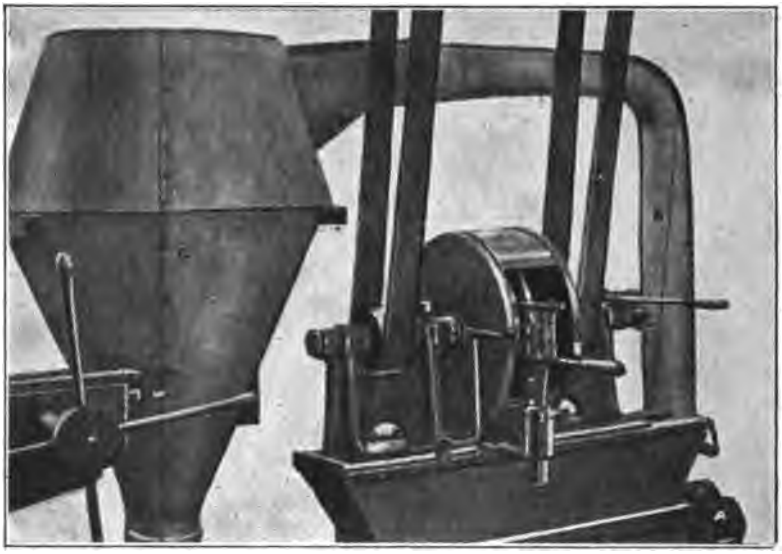


FIG. 143. DISK GRINDER AND DUST SYSTEM.

INDIVIDUAL SYSTEMS

There are numerous other practical and efficient systems employed in different factories; and in many cases where only one or two grinders are in service or where a grinding machine for some reason is operated by itself outside

the regular department, individual dust collectors have been devised and applied with very satisfactory results.

As an example of an individual dust system, Fig. 143 may be referred to. This shows a double disk machine for grinding hexagon nuts at the plant of the Nelson Valve Company, Philadelphia, Penn. A motor at the end of the machine drives the exhaust fan, which is connected by piping to the hood over the disks. The pipe leading from the fan to the dust bin leads up above and to the rear of the grinder.

DUST ARRANGEMENT FOR A GRINDING LATHE

Figure 144 illustrates a dust system described in the *American Machinist* by James Clark, as applied to a lathe arranged for doing considerable grinding.

The pieces to be ground were from 6 in. to 30 in. outside diameter, and a

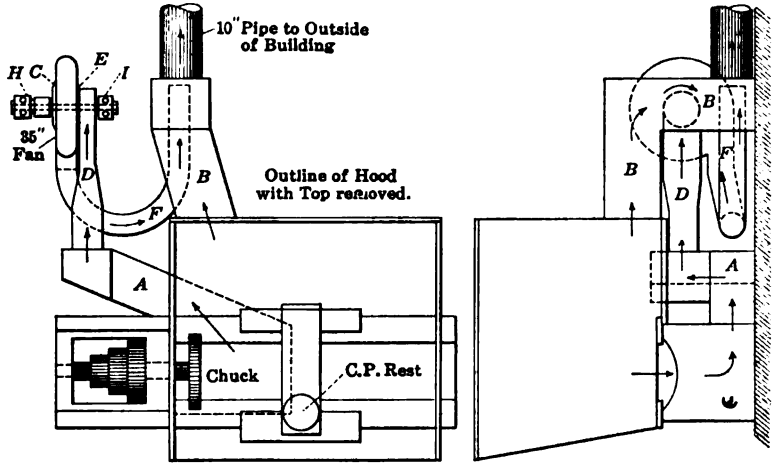


FIG. 144. THE ARRANGEMENT OF THE FAN OVER THE MACHINE.

light 36-in. lathe with short bed was selected for the work. Upon the compound rest of this machine a motor-driven grinder was mounted, this having a wheel 7 in. diameter by 3/4-in. face.

To overcome the dust nuisance, the apparatus shown in Fig. 144 was devised. A hood was built over the lathe as shown in the outline, with two outlets *A* and *B*. One-inch matched lumber was used in the construction. All openings through the lathe bed, except the one under the chuck, were closed. A box under the lathe bed and under this opening connects with the outlet *A*.

An extra forge fan, or blower, was on hand and this was used in place of a regular exhaust fan. To use this, the side opening *C* was closed with a plate, and the pipe *D* was connected to the other side opening *E*. The fan not having to work against much pressure, only one belt was required. The air and dust are drawn from the region of the chuck downward and through the tube *A*

and the pipe *D* to the fan, then forced out the pipes *F* and *G* to the outside of the building. A suction is also produced by the air when passing from *F* to *G*, thus causing a current through the tube *B*.

Since the installation of this apparatus there has been no trouble whatever from emery dust. In fact, a person standing less than 4 ft. from the wheel cannot detect any smell of dust.

FIG. 145. WET BELT FOR CATCHING DUST FROM SURFACE GRINDER.

It was necessary to use the 180-degree elbow, due to the direction of rotation, which could not be changed without running a crossed belt. Otherwise, the construction could be simplified somewhat.

WET BELT FOR CATCHING DUST

The engraving (Fig. 145) illustrates a device in use at the works of Alfred Herbert, Ltd., Coventry, England, for gathering emery and metal dust from

work which is of a character that precludes the possibility of making use of exhaust apparatus. It consists of a wet-belt attachment, which is shown in the illustration, as located at the side of the Brown & Sharpe surface grinder, the belt being carried on a roller which is given an intermittent motion by pawl and ratchet operated by the small grooved pulley directly above. The lower roller is located in a water tank in which the fine dust is deposited as the belt passes through the water. A number of these belts are in use at the Herbert works, and have been found very efficient.

DATA PERTAINING TO EXHAUST FANS FOR WHEELS

The growing recognition of the necessity for exhaust systems in connection with all grinding and polishing operations has brought out the fact that few seem to have definite knowledge as to the exhausters required. With a view to securing definite information along that line we have communicated with makers of blowers, and some of the data secured follow. We commend these facts to the consideration of those who have grinding and polishing rooms as a guide in installing exhaust systems.

FAN CAPACITIES, PRESSURES, PIPE SIZES, ETC.

C. A. Booth of the Buffalo Forge Company supplies the following particulars relating to the capacities of blowers and exhausters, the pressures for various purposes, sizes of pipe required, etc.:

The centrifugal type of fan discharges a volume of air which is an inverse ratio to the resistance encountered to its passage. That is, if the piping is small and of considerable length and contains obstructions to the passage of air, the volume may be considerably reduced. On the other hand, if running with practically unrestricted inlet and outlet, the fan will discharge much more than its normal volume and the efficiency, which is at the best about 50 to 55 per cent., will be less in either case, that is, when delivering more or less than the normal quantity. The normal capacity is given in the table for various speeds, under headings which show the total pressure against which this capacity will be discharged and the horse-power required. These tables are from actual tests and are correct, although it will be understood that under certain conditions a fan may deliver either more or less than the tabulated quantities and will require either more or less horse-power than the tables give.

Size of inlet	½ Oz.			1 Oz.			2 Oz.		
	R. p. m.	Cap.	H. p.	R. p. m.	Cap.	H. p.	R. p. m.	Cap.	H. p.
5¾ in.	1,693	104	0.023	2,396	148	0.074	3,393	210	0.233
6 1/16 in.	1,397	264	0.059	1,976	374	0.187	2,800	534	0.593
7½ in.	980	438	0.098	1,387	621	0.310	1,965	888	0.987
9 in.	859	585	0.130	1,216	828	0.414	1,724	1,174	1.300
10⅜ in.	776	837	0.186	1,098	1,185	0.593	1,556	1,688	1.870
12½ in.	635	1,185	0.263	898	1,677	0.839	1,274	2,382	2.650
14 in.	582	1,372	0.305	823	1,941	0.971	1,168	2,752	3.060
16 in.	499	1,986	0.440	706	2,810	1.405	1,001	3,983	4.430
17½ in.	411	3,299	0.733	581	4,668	2.334	824	6,641	7.300
21 in.	349	4,488	0.997	494	6,350	3.175	702	9,003	9.900
	3 Oz.			4 Oz.			6 Oz.		
5¾ in.	4,169	258	0.382	.....	.....	.....	.....	.....	.....
6 1/16 in.	3,437	651	0.964	3,977	753	1.37	.....	.....	.....
7½ in.	2,414	1,090	1.615	2,794	1,261	2.29	3,436	1,551	3.86
9 in.	2,119	1,441	2.135	2,452	1,667	3.03	3,015	2,051	5.13
10⅜ in.	1,912	2,071	3.08	2,212	2,397	4.36	2,721	2,948	7.37
12½ in.	1,563	2,923	4.33	1,809	3,382	6.15	2,225	4,160	10.40
14 in.	1,434	3,377	5.00	1,660	3,908	7.10	2,041	4,806	12.00
16 in.	1,229	4,888	7.24	1,422	5,656	10.20	1,748	6,957	17.40
17½ in.	1,012	8,150	12.10	1,171	9,431	17.10	1,440	11,599	28.90
21 in.	861	11,050	15.00	966	12,786	21.90	1,225	15,726	37.00

TABLE 27.—SPEEDS, CAPACITIES AND HORSE-POWER OF BLOWERS AND EXHAUSTERS.

This normal capacity of the centrifugal fan depends on the dimensions of the blast wheel and on the speed. A properly designed centrifugal fan will have a capacity which may be expressed by the following formula:

$$C = 3.14 \times N \times D \frac{(DW)}{3}$$

In which D and W represent the diameter of the wheel and the width at periphery in feet, and N the number of revolutions per minute. The area $\frac{DW}{3}$ is known as the "capacity area," or "equivalent orifice," being the area of an opening in a thin plate which will permit a centrifugal fan having a blast wheel with diameter D and width at the periphery W, to discharge its normal capacity.

In regard to the actual application of these fans for emery wheels, tumbling barrels, etc., the lighter the material which is to be conveyed, the less pressure is required, other conditions being equal. For buffing and polishing wheels, 3 oz. pressure is usually quite sufficient, and for heavy grinding or similar work the pressure required may be run up to 4 or 4 1/2 oz., which is also suitable for carrying away dust from tumbling barrels.

Small buffing, polishing and grinding wheels up to 12 in. diameter would require a 3-in. pipe only. Larger wheels, 14 or 16 in. diameter, should take a 4-in. pipe.

The hoods used with grinding wheels should be of an adjustable type so that as the wheel wears down the hood may still fit it closely and carry away the dust.

To determine the size of exhaust fan used for a number of wheels, the sum of the areas of the branch pipes is taken and a fan selected which has an inlet of an area equal to this sum of the branch pipes. This fan should be operated at a pressure suitable for the work to be done, and the speed and horse-power will be in accordance with table given.

PIPE SIZES DETERMINED BY NATURE OF WORK AND METHOD OF OPERATION

D. F. Carter of the B. F. Sturtevant Company points out the difficulty of giving fixed rules for the use of blowers for removing dust from grinding and strapping machines and buffing wheels, and states that in nearly every case the application of an exhauster to remove the dust from a mechanical process, demands separate analysis before the most economical exhauster for the work can be specified.

The first thing is to determine what size pipe is required to collect the dust at the machine. This depends entirely on the machine itself, and the way in which the dust is thrown off by the process. If the dust is concentrated at a point where it may be easily confined by a hood and deflected into the suction pipe, a 3 1/2- or 4-in. pipe is sufficient on average grinding machinery. This would apply to grinding wheels of from 12 to 16 in. diameter, and 2- or 3-in. face. Small emery belts would be treated in the same manner. For buffing work a slightly larger pipe is required than in the case of grinding, as while the dust is light, it is usually more widely distributed than in the case of grinding.

Surface-grinding machines are usually more difficult to handle, and larger pipes are required. This is due to the fact that the relation of the work and the grinding wheel is such that a hood cannot be located at the most advantageous point.

Where practicable, one blower is used to exhaust from a number of machines and branch pipes lead to each hood. This is usually a more economical arrangement than a separate blower for each wheel or stand. A small fan should be ample to carry the dust from one or two wheels with a short suction and discharge pipe delivering into the air, while if a screen dust collector is used at considerable distance from the fan, a larger blower would be required.

EXHAUSTERS FOR CYLINDER GRINDERS

In grinding cylinders for automobiles and other gas engines, it has become customary to use exhaust fans for removing the metal cut away by the wheel, and

the particles of the grinding wheel itself. This leaves the surface of the work clean for the grinding wheel, particularly in the machines where the wheel travels around the bore of the cylinder, as, if the grindings are not removed, the wheel must pass through them at each revolution.

As there has been some question in regard to the size of exhaust fan required to handle this work properly, the following particulars from builders of grinding machines showing what their experience has proved necessary should be of interest.

The Brown & Sharpe Manufacturing Company states that it uses a No. 00 Sturtevant exhaust fan of the Monogram type, having an inlet 4 7/8 in. in diameter, and an outlet of 4 1/8 in., the fan being run at 2800 r. p. m., and consuming about 1/8 horse-power; this being given as 3/8 horse-power for 4000 revolutions, according to the makers of the exhauster.

The power required depends on the conditions in which the fan is used, and whether the suction is through a long line of pipe, or whether it is close to the machine. In their later machines, where the exhaust fan forms a part of the machine equipment, the receptacle for grinding is at the base of the machine itself, the power would be at a minimum, presumably in the neighborhood of 1 horse-power at the speed mentioned.

In connection with this subject, the Heald Machine Company writes:

"We are using fans of the American Blower Company's make, known as their A.B.C. type 'V,' size No. 1, which has a wheel 8 1/2 in. diameter with a case about 14 in. diameter, having an inlet of 4 3/4 in. These fans, we believe, require about 1/2 horse-power and run 3500 r. p. m., delivering about 2 oz. pressure."

CHAPTER IX

THE CHIPS OF THE GRINDING WHEEL

There have been numerous discussions in the past regarding the nature of grinder chips, and some mechanics have taken the viewpoint that the action of the wheel was not a true cutting action, that the metal was rubbed or "pushed" off. The theory has also been advanced that the process of grinding consists "partly in shearing off minute particles of metal and partly in causing the metal to flow into cavities." Still another suggestion formerly made was that the metal was "burned off."

As long ago as December 27, 1900, Morris Fulton suggested, in the *American Machinist*, that a microscopical study of the chips produced by grinding operations might prove interesting, suggestive and profitable. Acting on this hint, Walter Gribben and W. A. Warman some years ago made micro-photographs of chips of various materials, and these are reproduced in Fig. 146. All of the specimens were ground under a flood of soda water, and they all show chips as clean cut as though produced by a good lathe tool. Of course, the halftones cannot show the color of the chips; nearly all of which, of steel or iron, are drawn to a blue.

The table herewith gives the data of the different jobs, as far as they were obtainable. The chips were originally mixed with particles of the abrasive, but nearly all of these were washed away from the chips in the process of mounting them for examination. In Fig. 148, *D* shows chips produced by a milling cutter of an engraving machine, and these are shown to give, by comparison, a better idea of the work of the grinding wheels. All of the specimens are magnified the same amount, about 32 diameters. In Fig. 147, *A* seems to give the hardest blow to the common idea of the action of a grinding wheel. For hardened tool steel to give a smooth chip of such length is a result one would little expect. Figure 148,*B* was found somewhat difficult to photograph on account of the large size of the chips.

In attempting to compare these "chips" with those made by the single cutting tool of the lathe or planer, it must be remembered that these are made by a practically infinite number of cutting points, no two of which are alike in shape, in size, in depth of projection, in speed of action, or in any particular akin to the precise conditions of the steel tool. It is no wonder that such a variety of forms and sizes is shown. The grinder evidently discovers the differ-

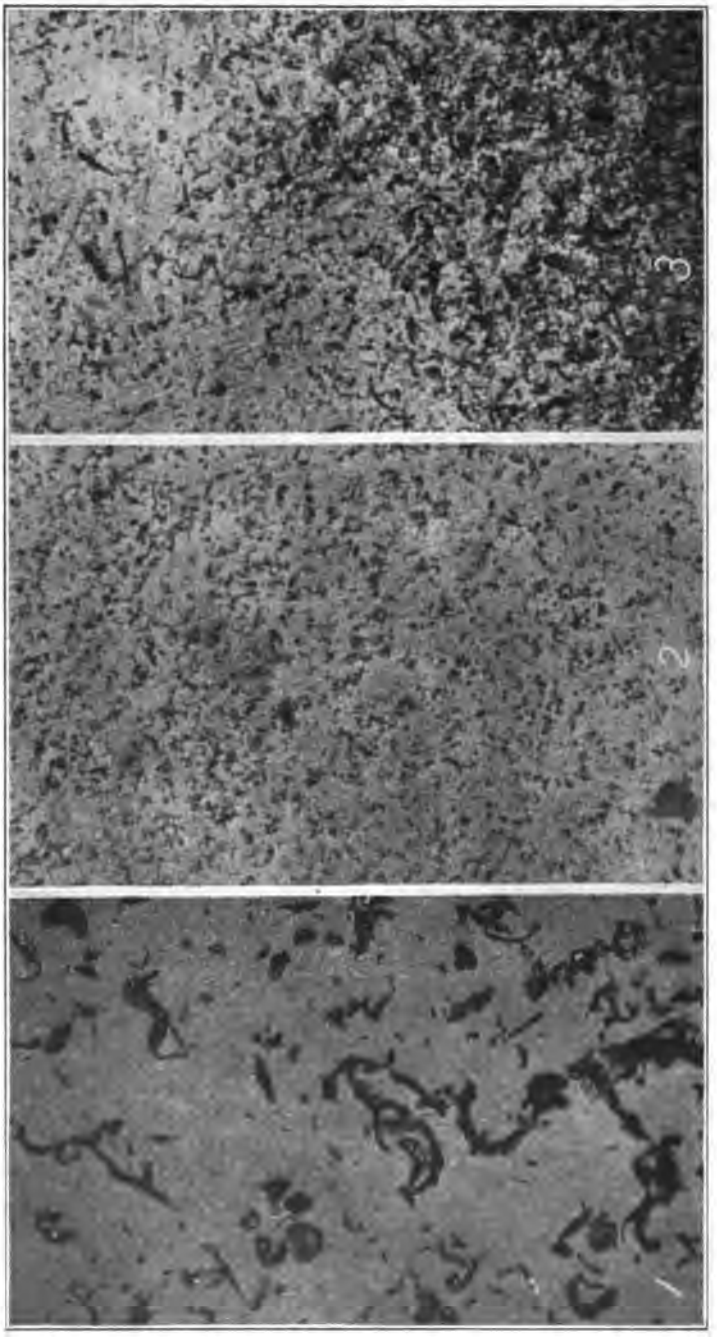


FIG. 146. GRINDER CHIPS—MAGNIFIED 32 DIAMETERS.

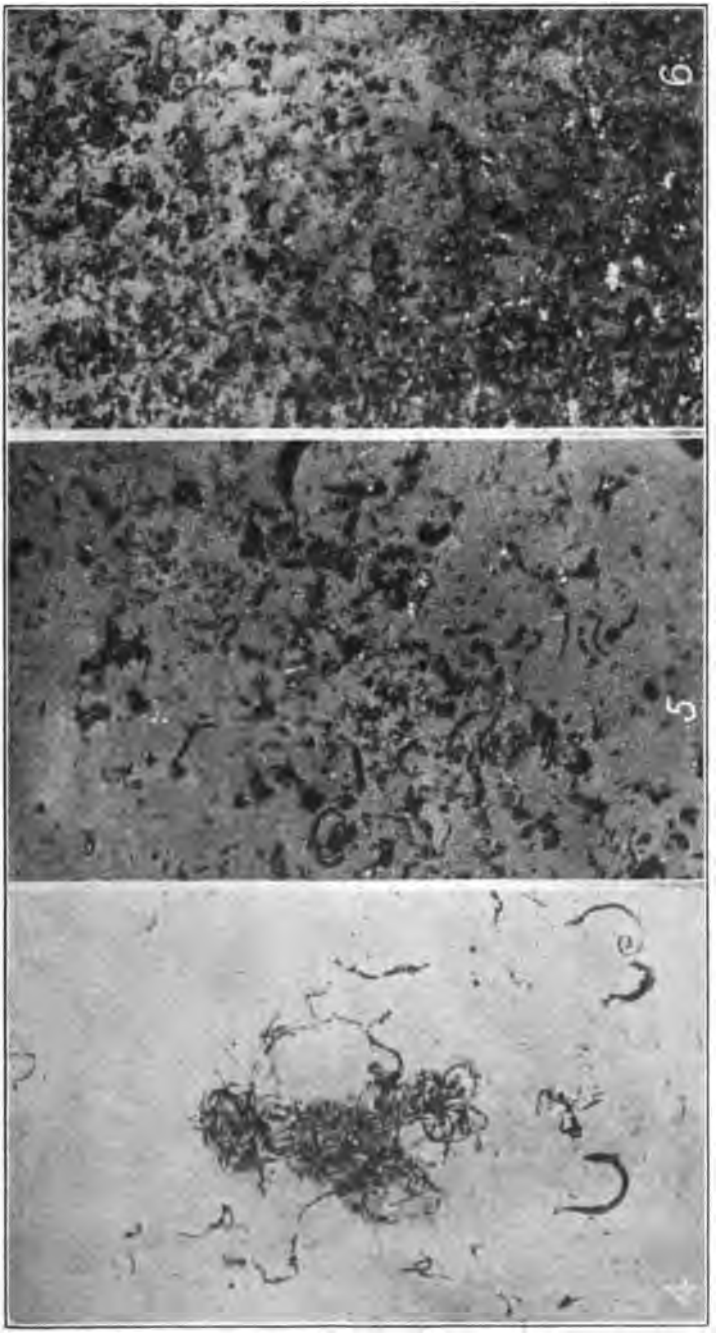


FIG. 147. GRINDER CHIPS—MAGNIFIED 32 DIAMETERS.

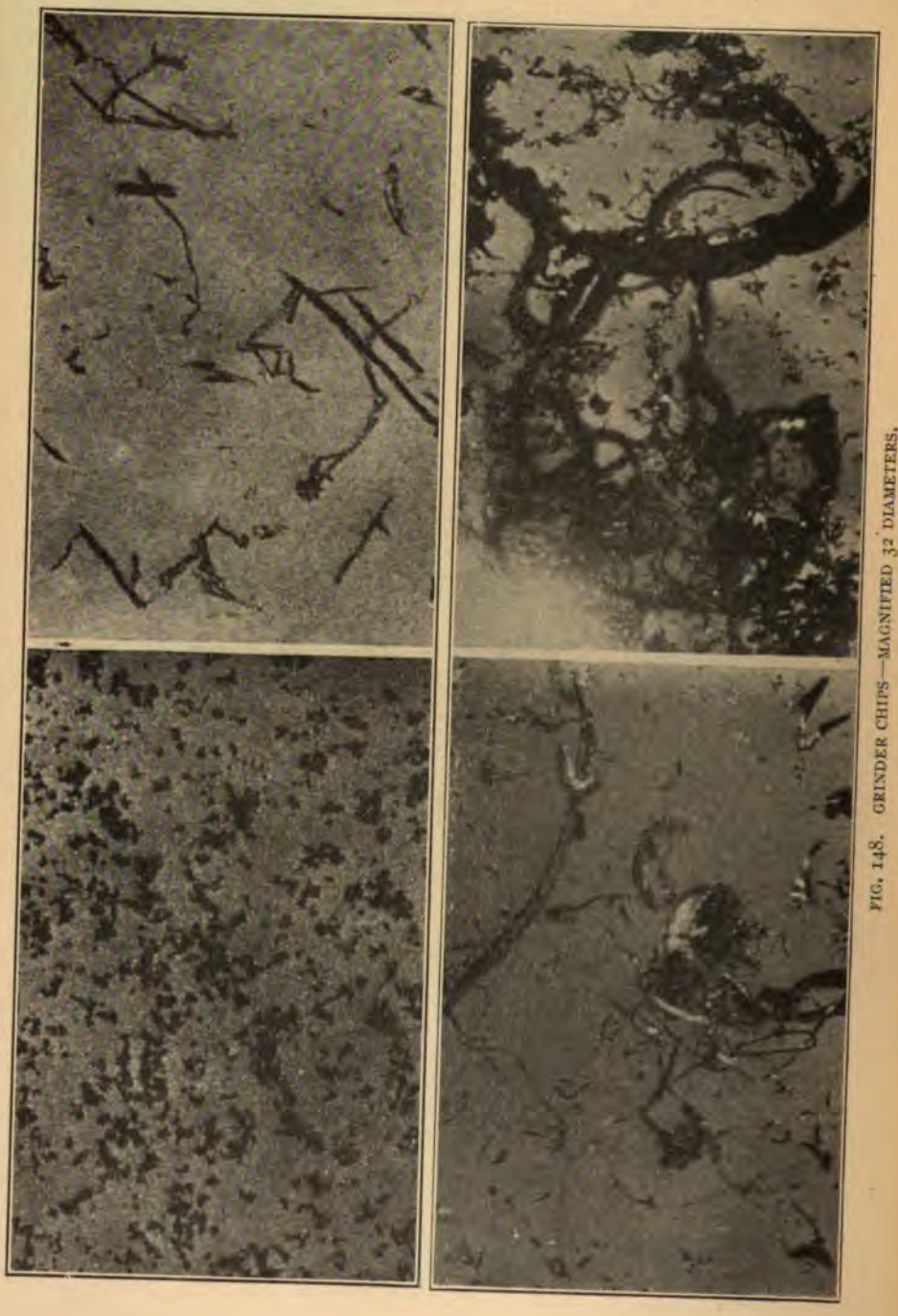


FIG. 148. GRINDER CHIPS—MAGNIFIED 32 DIAMETERS.

ence between hard and soft material, or between easy and difficult cutting as certainly as the steel cutting tool does, the chips from the hard metal, as *A*, Fig. 147, being so fine and attenuated as compared with those from the softer materials.

RIBBON CHIPS[1]

Some peculiar chips made by the grinding machine without using wheel traverse are illustrated in Fig. 149. The method of producing these ribbons was accidentally discovered while regular work was being done on a medium-sized machine.

The part operated on, as will be seen from the halftone, was a small spindle. The operation was reducing the end of this spindle, from 1 3/16 to 15/32 in. in

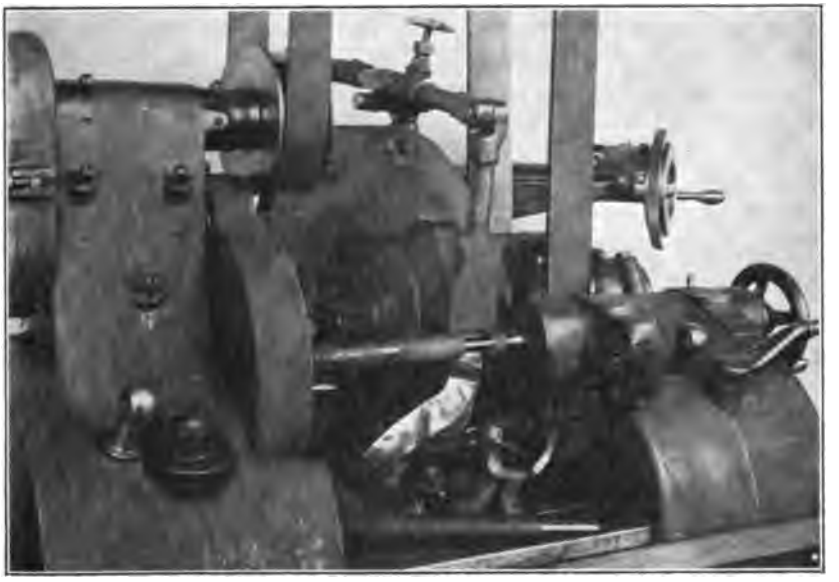


FIG. 149. A PECULIAR GRINDER CHIP.

diameter for a distance of about 2 1/4 in. back from the end. The wheel used was 1 1/2 in. face, and was first sunk in without traversing until the required diameter was obtained, leaving about 3/4 in. at the end which was then reduced to the same diameter in the same manner. These two operations constituted a roughing cut, and the end was afterward finished in the usual manner. A completely roughed out spindle is shown lying on the bed of the machine. It was from the first sinking in that the best chips were obtained.

The material from which the spindles were made was about 40 carbon steel.

[1] H. P. Noyes.

hardened. The work was rotated very slowly, at a surface speed of about 1 ft. per minute, while the emery wheel was run at about the maximum, 6000 ft. The best chips were obtained with the wheel slightly glazed.

During this operation 65 spindles of this description were roughed out and the metal was removed at the rate of 1 3/4 cu. in. per minute. The wear of the wheel, including truing up with a diamond several times, for roughing out the 65 spindles, was only 3/16 in. diameter. The wheel used was 18 in. in diameter, 1 1/2 in. face, grain 46, grade L. Some of these chips were obtained in lengths of 2 ft. or over with much the same curl as if they had come from a lathe.

Various theories have been proposed as to the cause of these chips. The most likely one seems to be that the rapid removal of metal and the very slow work speed allows a portion of the particles to become fused together as they leave the wheel. It is estimated that probably four times as much metal was removed at the time as was found in the fused chips. While the grinding operation is going on, the particles leave the work in apparently, a solid red stream of metal. That considerable heat was generated at the point of contact is evident, yet the work was not allowed to become heated.

The work was done on a No. 22 Landis grinder, a 12-in. swing machine. The weight of headstock and footstock was about 500 lb. and of the emery-wheel base 500 lb. The spindles ground were about 12 in. long.

It has been found to be advantageous to remove this large amount of metal on the grinder, not only on account of the rapidity of removal but also because before, when the end was roughed out on the lathe, and the spindles then hardened, there was considerable loss in hardening, the spindle snapping off or cracking near the shoulder, while now this difficulty is entirely obviated.

This form of chip, as noted above, was produced by accident and was not the result of any carefully extended experiment, and perhaps the way the chips occurred may be of interest: While doing some heavy roughing the wheel became glazed and the operator, an inexperienced hand, thinking it was not cutting properly, threw the belt to a higher speed which ran up to considerably over 6000 ft.; the foreman noting the occurrence went to examine the work and noticed a slight formation or the beginning of the ribbons, and after continuing the operation then produced one of the coils illustrated. It was recognized at the time that these ribbons were a sort of freak of nature, but this method of reducing stock by sinking in straight without traverse during the grinding operation was so successful that it has been continued. It not only reduces the stock faster than is possible in any other known way, but also eliminates the loss in cracking which is bound to occur in a hardened spindle with a wide difference in two diameters, when hardened after the end is reduced to the small diameter.

The ribbons are turned out incidentally, whenever a visitor wants to see one made, but it is not every operator who can make one, as in order to do it he must throw overboard his preconceived ideas of grinding practice—let his

Number	Material	Donor	Wheel			Remarks
			Size	Grit	Grade	
1	Soft machine steel..	B. and S.	12 in. × 1 in.	Corundum No. 60.	K Vitrified.	
2	Bessemer rod case hardened.	B. and S.	12 in. × ½ in.	Emery No. 40	Vulcanite.	
3	Machine steel case hardened.	B. and S.	12 in. × ½ in.	Emery No. 36.	4 Elastic.	
4	Tool steel hardened.	B. and S.	12 in. × ½ in.	Corundum No. 60.	L Vitrified.	
5	Bronze.....	B. and S.	12 in. × ½ in.	Emery No. 36.	3 Elastic	
6	Cast iron.....	B. and S.	24 in. × 2 in.	Corundum No. 46.	4 Silicate	
7	High carbon tool steel unannealed.	C. H. Norton.		Corundum No. 24, 36 and 60, Equal parts	H	Ring wheel grinding on flat face, wheel speed 4000 ft. per minute, work speed 6 to 8 ft. per minute.
8						
9	Chilled iron.....	F. Thornely.	9 in. diam.	Emery No. 60	M	Heavy roughing cut, wheel speed 3000 ft. per minute, work speed 37 ft. per minute.
10	Tool steel annealed.....					Milling chips from Janvier Engraving Co.

TABLE 28.—DATA RELATING TO GRINDER CHIPS

wheel become glazed, run up the speed, and slow down the work speed, and take a very heavy cut.

The make of wheel has no bearing upon the operation. If the work is revolved very slowly (1 ft. a minute surface speed, or less) the wheel fed in rapidly, without traverse, and a wheel of rather hard grade used, these ribbons will be produced. With the same wheel, if the work is speeded up and traversed past the wheel the ribbon chips cannot possibly be produced.

CHAPTER X

WATER NOZZLES ON GRINDING MACHINES

Few of us have ever given any attention to the nozzle which supplies water to the emery wheel except when it gives us a shower bath or splashes water all over the machine. Water guards of various kinds have been devised to keep the water within bounds and prevent its being spread all over the floor.

But a nozzle has been designed which is free from these disagreeable habits and which is exciting much comment among those who have seen it. It was

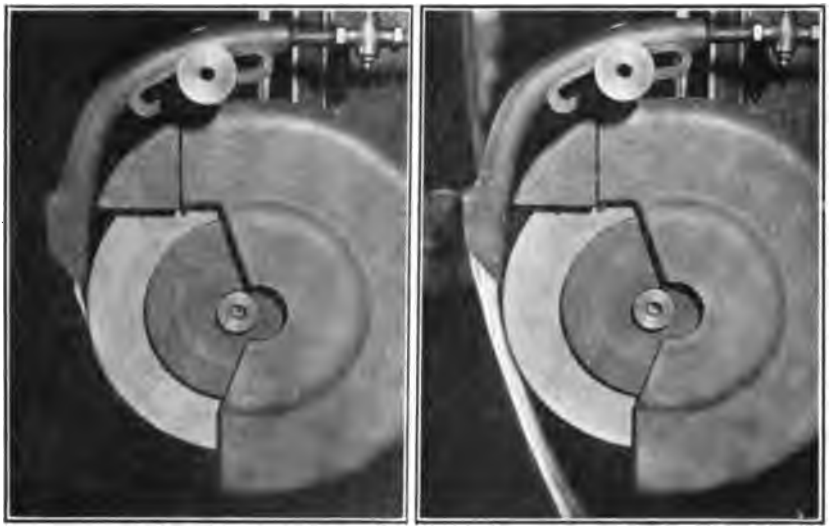


FIG. 150. NON-SPLASHING NOZZLE FOR EMERY WHEELS.

devised by John Bath of Fitchburg, Mass., and is being applied to all the Bath machines.

The two illustrations above in Fig. 150 show the action of the water as it comes out of the nozzle under extremes of condition, one with full head, the other with a very small stream, but in neither case is there any sign of splashing. In fact, there is a total absence of the water being blown away by the air or windage from the wheel as is usually the case. Stranger yet, note how the small stream actually curves back toward the wheel instead of being blown away from it. Many theories have been advanced for this action by the many different observers, but few have agreed as to the cause. The main point is

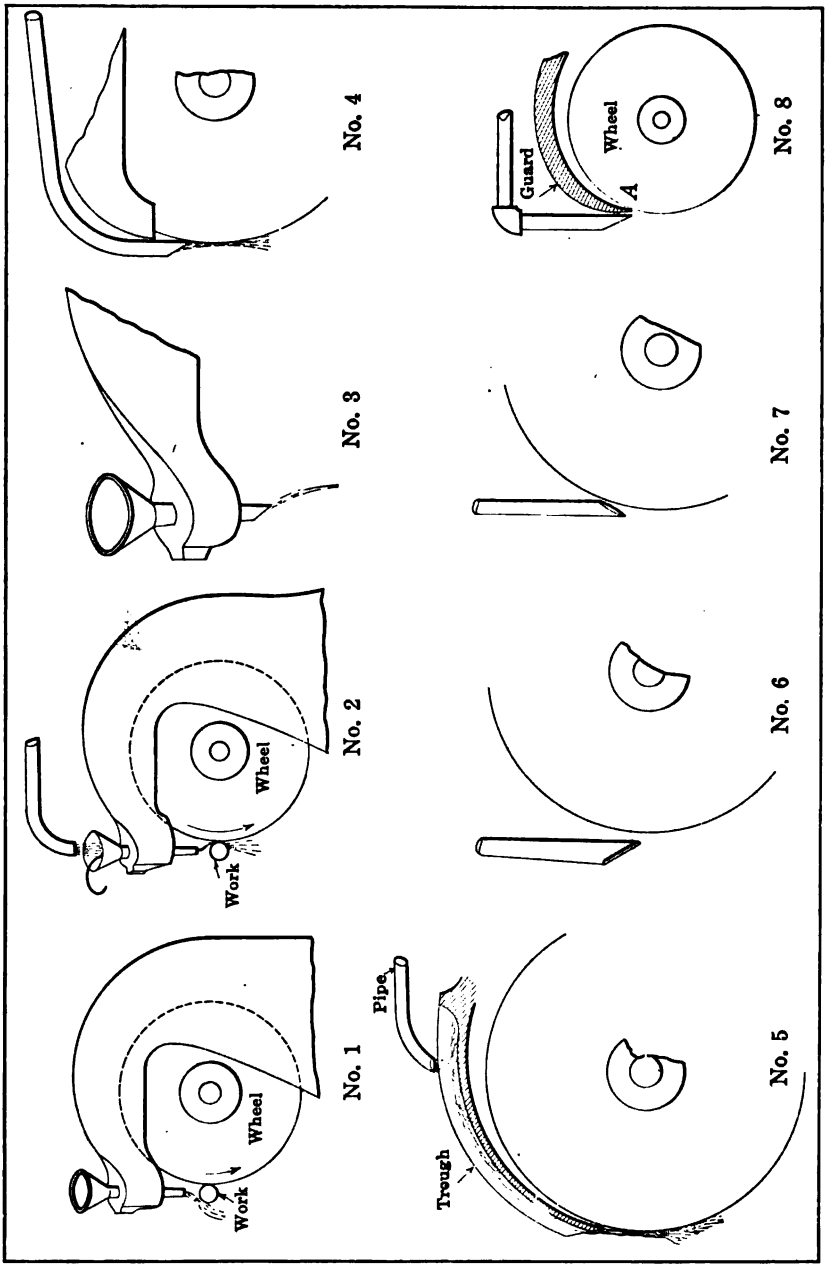


FIG. 151. A VARIETY OF NOZZLES AND THEIR ACTION.

that the water does not splash, as that is the most interesting to the user. It all goes directly on to the work and then some of it follows the wheel back into the hood, all finally running quietly down to the tank where it belongs.

WATER NOZZLE DEVELOPMENT[1]

It was some time in 1887 or early in 1888 that we had the following experience: In arranging for a very small stream of water on grinding machines a small funnel was made as shown in No. 1, Fig. 151. The water was dripped into the funnel from a pipe above, but water would many times be blown away from the wheel and work as shown. It was then noticed that workmen put a wire in the funnel as shown in No. 2, to guide the water on to the wheel and work. At that time no one expected to use more than a very small amount of water and the need of more water later, proved the wire scheme inadequate. Noting the action of the water on the wire, the idea was conceived of making the nozzle itself a hollow wire, as it were, and the funnel nozzle cut away on one side as in No. 3, with the desired result, as either a very small stream or a pipe full would flow toward the wheel.

We then fitted all Brown & Sharpe grinding machines with this form of nozzle, although the funnel was discarded and a pipe substituted as in No. 4, which is like the one shown by Mr. Bath, so far as the essential features are concerned.

Norton grinding machines have been supplied with this form of nozzle since their first appearance and this form would be ideal for small streams of water if it were not for the fact that users cannot, or will not understand that when they press the nozzle against the wheel it will be ground by the wheel like any other piece of metal, and that when the original shape of the nozzle is ground away the water will no longer flow toward the wheel but will be blown about and on the operator.

To overcome this trouble, to secure good results in spite of carelessness, or of accidents and to enable the operator to deliver the water in such quantity, such form, and at such an angle as may best serve his purpose with the great variety of conditions imposed by the various diameters and shapes of work, as well as depth of cut, width and grade of wheel, the deflector was designed and added to the original nozzle.

WHY NOZZLES DO NOT SPLASH

It is asked what causes the water to flow toward the revolving wheel through the air currents that are moving from the wheel.

It has always been a personal belief that capillary attraction was the cause. It seems evident that if one side of the pipe be cut away on an angle that the

[1] C. H. Norton.

water must follow the other side to, and off the point, and if the point be smooth and curved a little toward the wheel, that the water must continue to flow toward the wheel. When we consider that there is really very little force to the air currents from the face of the wheel, it is easy to understand that the water being heavier than air, when once started toward the wheel will penetrate the air currents.

The success, however, of this form of nozzle depends upon the mouth being so shaped as to deliver a smooth stream, as any stray drops will be caught by the air currents from the sides of the wheel and scattered, for the air currents from the sides of the wheel are quite strong.

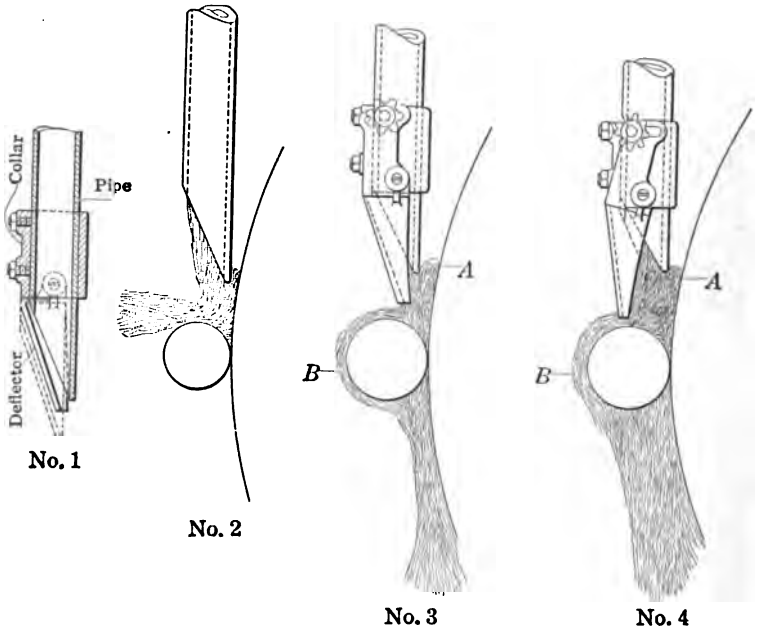


FIG. 152. WATER NOZZLE ON GRINDING MACHINES.

A wide, thin stream will be caught by the side currents and scattered. That part of the stream, however, that covers the face of the wheel only, will flow onto the wheel if delivered from a pipe cut at an angle or from a trough as No. 5, if the stream is not too thin or too light. In the latter case the water will be scattered by the air from the face of the wheel also. Now by using a pipe cut away on an angle and flattened like No. 6, we can deliver a thin stream and still prevent its being scattered as it is delivered edgeways to the air currents.

We can also deliver a large stream without its sides coming within the path of the side currents. The water nozzles for Norton machines were first made as in No. 6. It was discovered, however, that when large amounts of water

were required, a wide stream as well as a narrow one was sometimes necessary and that different conditions required that the water be delivered at different angles as well as different shapes of the stream. The deflector shown in Figs. 152 and 153 was designed to meet the requirements and added to the nozzle shown in Fig. 151.

Many operators will, if possible, turn the nozzle as in No. 7, in spite of the fact that water will then be blown directly on them. The one shown by Mr. Bath has the merit of being "fool proof" in this respect.

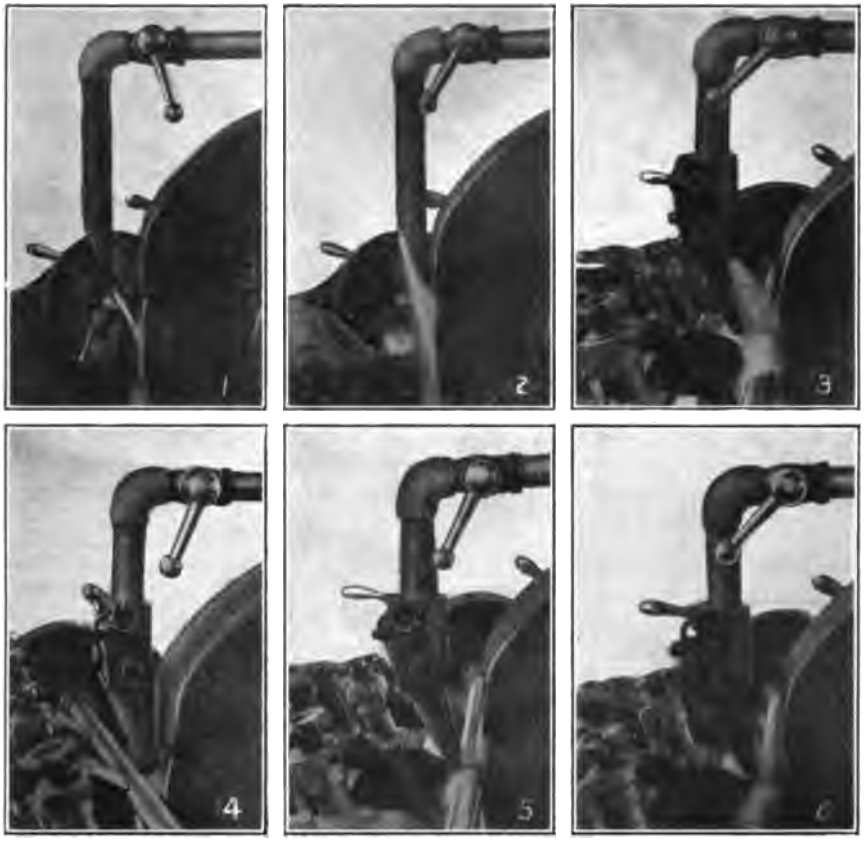


FIG. 153. ACTION OF VARIOUS NOZZLES.

OTHER POINTS TO CONSIDER

There are other points than the shape of the nozzle that must be considered. One important point is that the wheel guard should be made to just touch the wheel face at *A*, No. 8, as then there will be less air currents at the nozzle.

Many operators allow the guard to stand away from the wheel face and then get wet or wear rubber suits to keep dry. An operator who has not learned this simple fact about the water cannot lay claim to being a good grinder.

The water nozzle, at first made for Norton machines in 1900, is shown by Nos. 1 and 2, Fig. 153. It will be seen by a glance at No. 1 that a very small stream will flow directly toward the revolving wheel. So also will the larger streams in No. 2 flow smoothly when the wheel is revolving at full speed, but while a burning match is seen near the water in the photos it proves nothing because the wheel was not running when the match was burning, and no match will burn near a 2-in. face wheel that is running 6000 feet per minute, whether there be water there or not, for while the air currents from the wheel face are not sufficient to disturb the flow of water they will instantly extinguish a burning match. Thus the picture of a burning match in front of a grinding wheel and its water supply does not prove anything in this case.

Experience has shown that although a stream like No. 2 can be run smoothly from such a form of nozzle and against the face of a rapidly revolving wheel, yet when work is in position the water will be blown toward the operator as shown by No. 2, Fig. 152, if enough water is used to meet modern demands for production and a wide range of work.

DEFLECTING NOZZLE

It was to provide for the large range of work and the ever varying conditions affecting the water that the deflecting, adjustable nozzle was designed. Almost every different piece of work necessitates a different application of the water, if cleanliness and rapid production are secured. The direction of the air currents is effected by the diameter and form of the work, as well as the width of the wheel; while the intensity of the air currents is effected by variations of the position of the wheel guard and width of wheel face. Different conditions of work require different volume of water while different volumes of water require different angles of delivery to avoid spattering, and a round stream has to be applied differently on some work than a spreading stream. All of these results, however, are very easily obtained by the ordinarily observing man.

A study of Nos. 3 and 4, Fig. 152, and No. 3, Fig. 153, will show some of the different adjustments delivering the water to the work. The first two in Fig. 152 were drawn as it was found impossible to photograph water just as it flows on the work and wheel. It will be seen that it is easy to so adjust the nozzle and supply that the work will be engulfed with water and that the wheel face for a considerable space will also be covered with a heavy mass of water. This later feature was true in case of No. 3 and No. 6, Fig. 153 but the camera failed to show it clearly. Number 4 and No. 5 show the nozzle in different position and different adjustment of deflector with small amount of water.

Number 4, Fig. 152, shows the collar lowered on the pipe to give a large round stream.

There are many facts to be known in connection with the use of water with cylindrical grinding if rapid production, accurate work and cleanliness is obtained. Very few users of grinding machines have discovered what is to be known about the application of water to grinding work, for so far, the act of cylindrical grinding has not been given real study by the engineer. He has other problems to consider and has assumed that all that was necessary to do was to let water wet the wheel and that "A stream of water is simply a stream of water as everyone knows." When the engineer learns that everyone does not know, and when the foreman stops to think out the simple facts in order to intelligently instruct the operator, there will be rapid strides in the progress of the art, and great economies will result.

Human nature shows some interesting and amusing sides when it touches the use of water and water nozzles on grinding machines.

Who ever heard of a screw-machine operator who could not adjust the oil pipe to deliver oil on the work at the right place, and who could not turn the oil nozzle so it would not squirt oil on him if he found it doing so? Also who ever saw a shop using screw machines where they did not arrange such oil guards as were needed to protect the operator, and this without comment or complaint?

Such reasoning has seldom been applied to water and the grinding machine, unless the machine was homemade, when it has seemed to be all water guards. Who has known of a shop arranging different water nozzles for different kinds of work? Yet this is common when oil is used on screw machines.

SOME PERSONAL EXPERIENCES

Many amusing incidents have come under our notice at times. A new man was operating a grinding machine in our own works, and one day he asked in all seriousness for an oil-skin coat. When his trouble was investigated it was found that he was very wet by water that splashed on him owing to the position of the nozzle and angle of the stream against the work. The nozzle was properly adjusted and not a drop of water came over the machine table. This nozzle had convenient adjustments in all directions for this very purpose.

A large concern complained at the expense of rubber suits for the operator, the writer called to see what was the cause of the rubber-suit expense and found the operator clad in coat and high boots of rubber. The floor was spoiled by long soaking in soda water.

The nozzle was adjusted and not a drop escaped from its proper boundaries and after some explanations to the foreman, all appeared happy. A short time afterward a second call was made only to find the rubber suit again in use. Again the nozzle was adjusted and the rubber suit removed.

One foreman removed the pump because he was afraid someone would get water on the machine, and he was certain that it would spoil the machine to wet it. Another foreman concluded that the water nozzle should be screwed tighter so he took the pipe tongs and screwed it more, thus turning the nozzle back side front. In this case about half of the water was directed toward and on the operator.

At another works, they for some unknown reason, turned the nozzle back side front and then tied rags over the nozzle to keep water off from the operator.

A number of users have assumed that water was an unnecessary evil, and have spent good money in a vain attempt to grind dry.

CHAPTER XI

TRAVERSE SPINDLE GRINDER AND OTHER OPERATIONS ON SMALL WORK

The traverse spindle grinder is one of the most useful appliances to be found in the tool-room and on many classes of small work it is a valuable and almost indispensable manufacturing tool. Although primarily designed for watch factory purposes, it has taken its place to-day in other factories doing high-grade work, and will be found in the up-to-date tool-room along with other bench-lathe equipment.

TWO TRAVERSE SPINDLE ATTACHMENTS

Two types of traverse spindle grinders as made by the Pratt & Whitney Company are illustrated in Figs. 154 to 156. The first of these is adapted to be

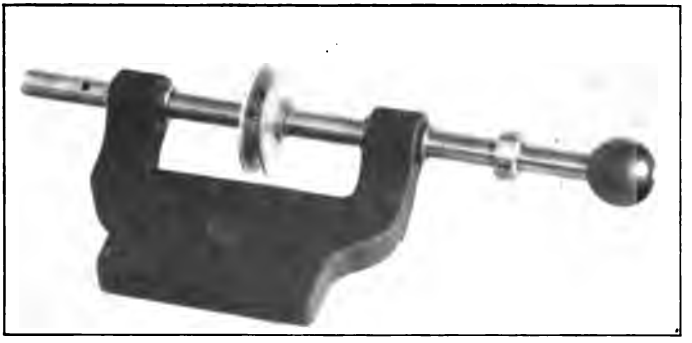


FIG. 154. SLIDE REST TRAVERSE SPINDLE GRINDER.

attached to the slide rest by a screw and nut, the latter passing into the tool post slot. It may be used for grinding or drilling holes, and general work. The slide rest screw locates the spindle at any desired point and it can be set at any angle.

The traverse motion of the spindle is controlled by a leather washer at the end or, better still, by the fingers engaging the sides of the pulley. The taper hole in the spindle has an included angle of 4 degrees, and the largest diameter of the hole is 0.2 in.

Figures 155 and 156 show the other type of traverse spindle which is so mount-

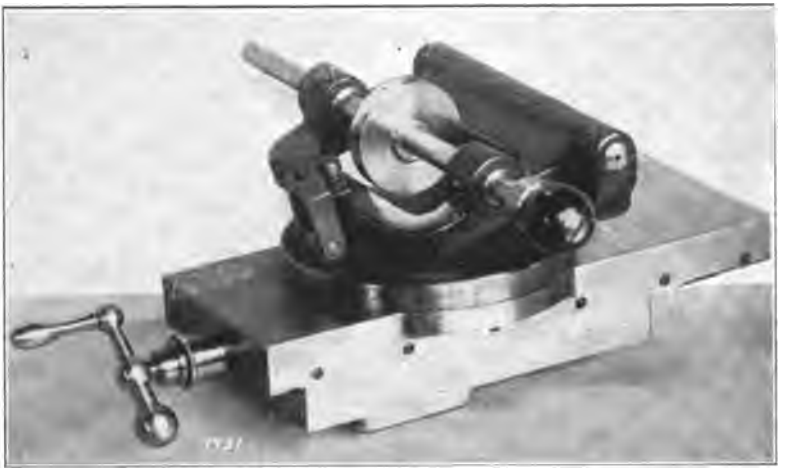


FIG. 155. A GRINDING REST WITH TRAVERSING SPINDLE.

FIG. 156. GRINDING REST WITH TRAVERSING SPINDLE SWUNG UP TO ALLOW THE WORK TO BE GAGED.

ed on a grinding rest that it may be adjusted vertically, as desired, swung entirely out of the way as in Fig. 156, to permit gaging of the work and returned to its proper position as determined by the stop. The spindle is carried in a rectangular frame which is supported at three equidistant points to give it a rigid support on the top of the slide. There is one slide only, which is operated by a screw with friction micrometer. The spindle is set at any desired angle with the axis of the work by means of the graduated circular base of the grinder head.

This attachment is particularly serviceable where precision grinding is to be done on a manufacturing basis.

The spindles in these traverse spindle grinders are 1/2 in. diameter, and run at speeds from 12,000 to 13,000 r. p. m. Both the bearings and the spindles are of hardened steel, ground and carefully lapped for straightness and fit.

OPERATING THE TRAVERSE SPINDLE GRINDER[1]

A few pictures of simple operations, intended merely to show the facility with which a single piece may be held and ground inside and out, may prove of interest.

Figure 157 shows the work held in a cast-iron spring chuck, with a closer on the

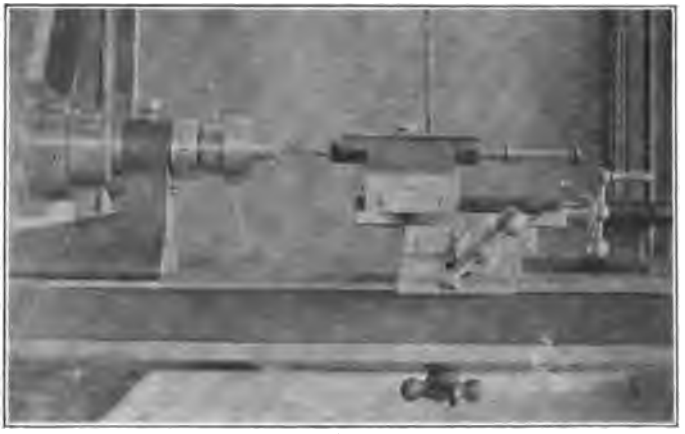


FIG. 157. GRINDING A SMALL HOLE.

spindle and a small wheel in position for grinding the hole. Figure 158 shows the spindle swung back to allow the hole to be gaged. This is a good feature, as it allows plenty of room and the wheel swings back to exactly the same position when locked by the small pin, shown pulled out just below the fulcrum pin.

Figure 159 shows the 3-in. disk wheel which will grind the diameter and face the shoulders of the work, or the rest may be placed on the offset shoe which

[1] W. H. Sawtell.

is fastened to the back T-slot, as in Fig. 160, and brings the spindle at right angles to the head spindle. Figure 161 shows the machine set up to grind a taper hole in a spindle. Figure 162 represents the operation of grinding small work between

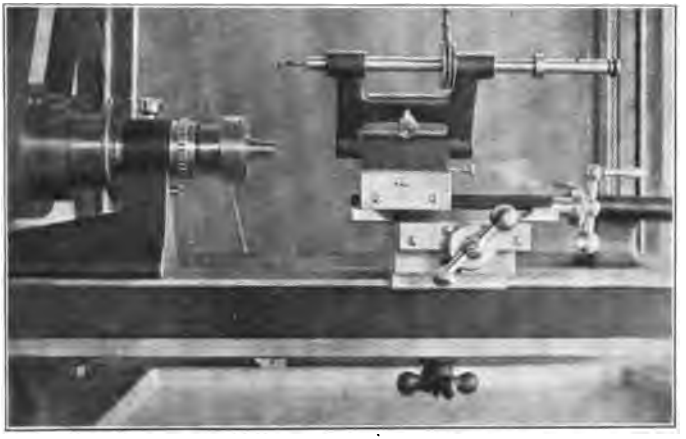


FIG. 158. GRINDING SPINDLE SWUNG UP FOR GAGING.

centers, a short tail stock being used with a spring center. Although these grinding fixtures seem light and delicate to the uninitiated, holes in 4-in. rings have been ground with them where 0.01-in. stock had to be removed, in one-

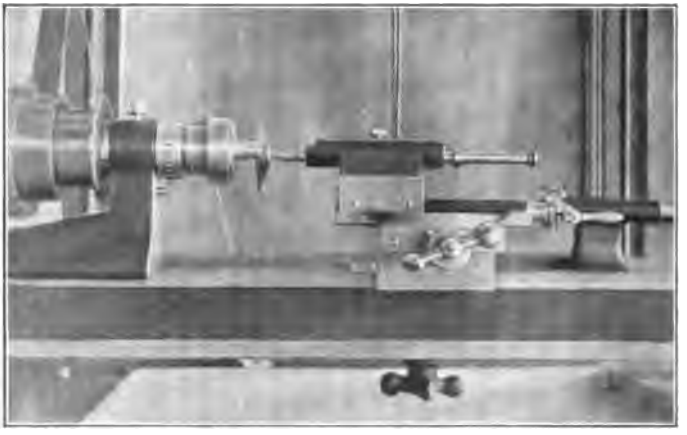


FIG. 159. GRINDING FACE AND SHOULDERS.

half the time it took to do the same job on a universal grinding machine. The traverse spindle, when properly fitted, will run without a particle of oil, if kept clean, and it is common practice to use it in this way.

Use clean tissue paper and alcohol to clean the spindle and clean out the bushings, being careful to keep oily fingers and belt from coming in contact with the spindle. After starting to grind, if the spindle shows any tendency to cloud

FIG. 160. GRINDING AT RIGHT ANGLES.

up or stick, it may be necessary to have a little wad of paper to rub it with, keeping the spindle revolving, and traversing, to reach as much of the surface as possible. The spindles, however, which will run absolutely dry, are rare,

FIG. 161. GRINDING A TAPER HOLE.

almost as rare as the men who understand making and using them. Most of the spindles which are made to sell are fitted slightly free, and require the least bit of lubricating.

The best thing for this purpose is a piece of clean waste wadded up tight to about the size of a walnut. Put a couple of drops of watch oil on this and apply while the spindle is revolving, traversing back and forth several times to thoroughly clean it. If the spindle appears to gum or cloud up don't be afraid to keep at it, and after a few cleanings it will settle down to business and give no further trouble.

When a spindle becomes worn, so it shows the least particle of shake, it should be relapped to straighten it, using a cast-iron lap of generous length and washed flour of emery, the finer the better for the final finish, when all loose emery should be washed from the lap. Then after removing the old bushings the casting may be lapped slightly, to correct any change which may have taken place.

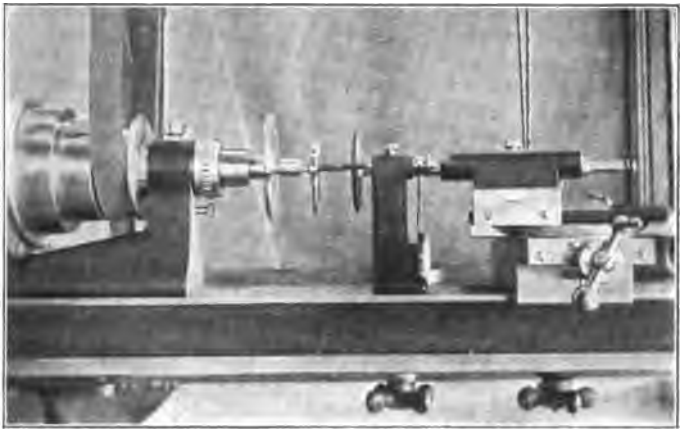


FIG. 162. GRINDING SMALL WORK BETWEEN CENTER.

Make new bushings of good tool steel, harden, grind and lap the hole to a good, tight fit on the spindle, which may be used as an arbor to finish the outside of the bushings on. Leave the bushings a tight fit for the casting, and after pressing into place lap with a good straight close fitting cast-iron lap, long enough to reach clear through both bushings. After the spindle will enter, the spindle and bushings may be lapped together by using "XXX" washed flour of emery very sparingly, frequently cleaning and testing at high speed to determine when the right freedom is gained.

These spindles will stand remarkably high speeds and form when used clean, an air bearing. When a belt lets go while running at high speed the spindle will frequently run for two or three minutes, but at the same time when standing still it will be difficult to slide it in its bearings, so close is the contact.

OTHER WORK ON THE TRAVERSE SPINDLE GRINDER

The variety of operations that can be performed with the traverse spindle grinder is remarkable. There is also an endless number of operations that are accomplished with the aid of other grinding attachments for the bench lathe and watch lathe.

Some illustrations in addition to those already shown by Mr. Sawtell are presented below, with brief explanation.

One of the important undertakings in which the traverse spindle grinder is found indispensable is the making of small master plates where small, deep

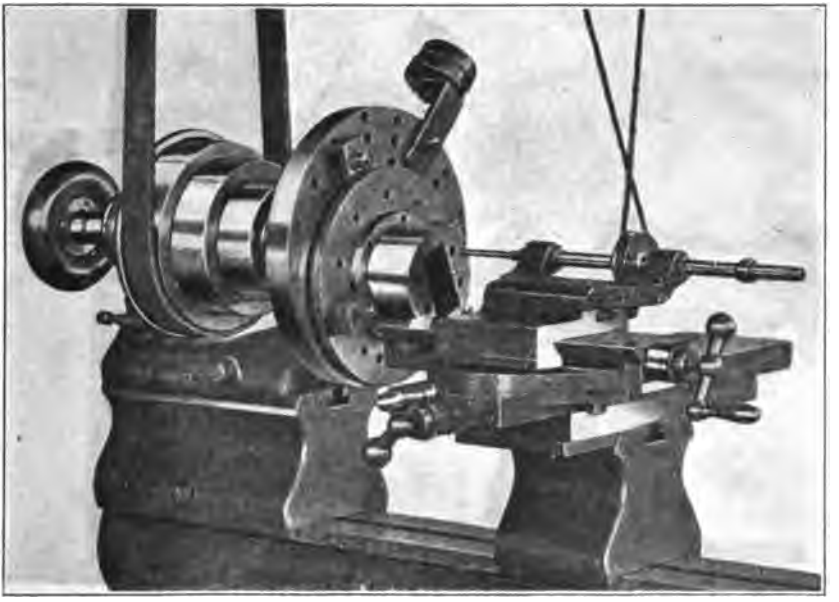


FIG. 163. A GRINDING OPERATION.

holes are required to be accurately ground. An operation of this nature described by E. H. Crosby is shown in Fig. 163, which represents the grinding of four holes in a piece of work. The holes were transferred into the work before hardening, on the same master plate and after hardening it was remounted for grinding them to again match the master plate. The master plate is located on the face-plate for each hole in the usual way by a centering plug in the lathe spindle. The lathe head and the slide rest holding the traverse spindle grinder are set high above the lathe bed on raising blocks so that the weights used for counter-balancing the work will clear the lathe bed. In the end of the traverse spindle is mounted a steel lap charged with diamond powder for grinding the holes.

MOUNTING WHEELS ON THE SLIDE-REST GRINDER

Figure 164 shows a grinding-wheel mount which is used in the slide-rest grinder for the bench lathe. As described by Gus Haessler, it consists of two brass flanges, and a steel arbor. To prevent the rear flange from unscrewing when removing the wheel a drop of solder may be applied at the point indicated. The wheel is secured by placing it on the fixed flange while the other is screwed

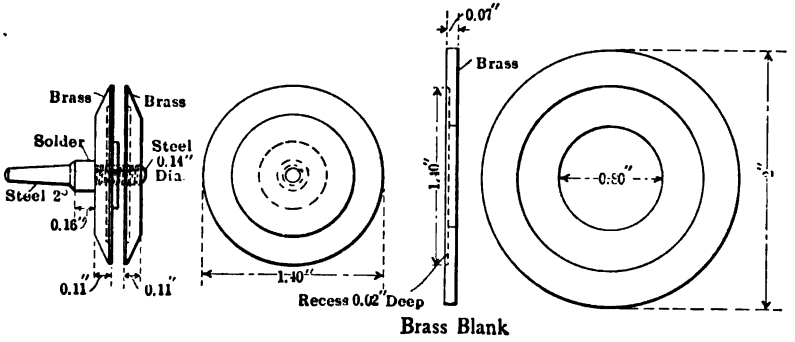


FIG. 164. ABRASIVE-WHEEL MOUNT.

on as far as possible with the fingers, then grasping the wheel by its periphery and turning, additional security can be obtained as the movable flange is carried with it, and consequently it is loosened when the wheel is turned in the contrary direction. Figure 165 shows one of these converted into a mount for a disk wheel by means of two brass blanks and three or four screws. One of the

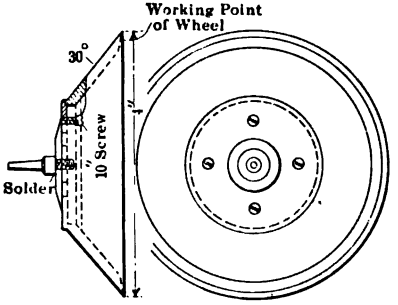


FIG. 165. DISK-WHEEL MOUNT.

blanks is recessed for the fixed flange in Fig. 164 which is sweated into it. The arbor can now be placed in a taper chuck while the flange is faced and turned off. At this point the flanges may be clamped together for drilling the screw holes. All that is now necessary is to counterbore and tap the holes, and chamfer the movable flange as in Fig. 165, then turn the groove for the wheel

seat which can be ground in by holding the wheel in the hands while the mount is revolving. This wheel is used for grinding thin slotting saws for clearance and thickness. The method of doing this consists of chucking a piece of brass and recessing it to a depth somewhat less than the thickness of the saw and a trifle larger than the diameter. The saws can then be inserted with the thumb while the lathe is running, and the engagement of the teeth in the recess is sufficient to drive them when the wheel is moved up to the work and withdrawn at intervals. A receptacle can be placed under the chuck to catch the saws as they drop out. Occasional measurement of the saws makes it easy to get the thickness required, while the clearance is obtained by swinging the slide rest.

The following was copied from the tag on the abrasive wheel.

Size 4×3/4×1 3/4
Grade E
No. of Corundum 90 [Craig Mine Crystal]
No. of Revolutions 4775.

If no other means are at hand to determine the speed at which the wheel should run, a simple way is to place a finger close to the lathe belt, and count the impulses of the joint in its revolutions for one minute. Next, make a chalk mark on the wheel opposite the belt joint and pull the belt around one revolution, meanwhile counting the revolutions of the wheel. The product of these gives the number of revolutions per minute of the wheel. In the present case the number for the belt is 117, and for the wheel is 41 for each revolution of the belt. Multiplying gives 4797, which is close to directions and gives good results.

GRINDING A CUPPING TOOL

Two grinding operations performed on the cupping tool, shown at *A* in Fig. 166, which is used for cupping out main-spring barrels, may be of interest. Few preliminary arrangements are made for grinding when only a few of these are needed, but when made in lots of 40 or 50, it is desirable to have tools and a good method of handling, to facilitate the work.

The angle of the tool in process of grinding is shown at *B*. As indicated, the feed screw has been removed for the purpose of permitting the slide to be moved to and fro, while the adjustment of the wheel to the work is made through the handle of the upper slide. A recess was turned into the side of the wheel a short distance from its periphery, thus making a complete passage of the wheel across the work unnecessary, and consequently shortening the stroke of the slide. The gib screws of the lower side were so adjusted that it responded to a slight push or pull when it moved across the work by hand.

The cutters were all milled to the same size, leaving 0.003 or 0.004 in. to grind, and after hardening they were first ground to the required diameter, the angle or cutting edge being ground last.

In reference to the sketch, the semi-diameter of the tool is sometimes ground

with the slide-rest grinder, setting the flat part square with the lathe bed, but the objection to this is that it leaves the surface concave when the wheel is traversed parallel to its length, so the following method is prefered: A tool is placed in the chuck with the flat side down, and the gage *C*, fitted to the T-rest, is so adjusted to it, that when the work is indexed half-way around, the flat side is up and ready to grind; then the milling attachment is set to zero and the lower slides moved to and fro with the left hand while the right operates the feed-screw handle.

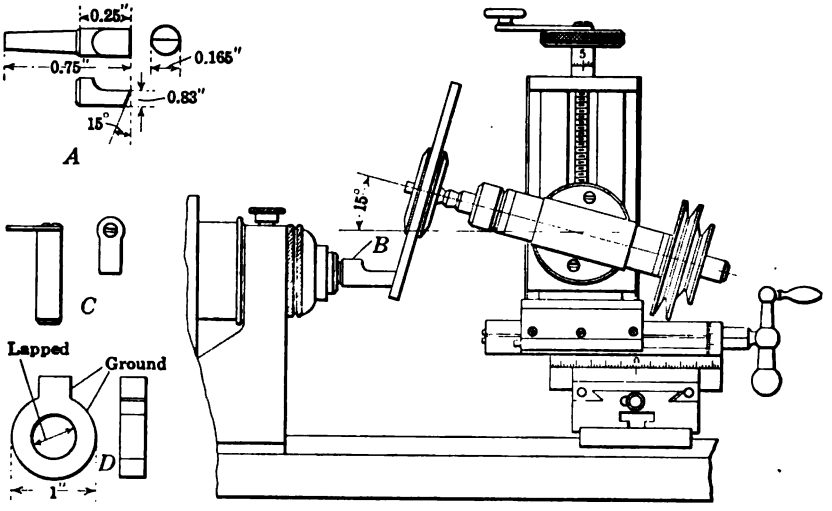


FIG. 166. GRINDING A CUPPING TOOL.

A corundum wheel, 120 grain was used, which was reduced very little in diameter after grinding 50 cutters, and by noting the graduations on the milling attachment, accurate measurement was easily obtained.

At *D* is a job of transverse cylindrical grinding, which can be done by removing the screw from the upper slide and setting the milling attachment so that it can be fed across the work in the same manner as described. The usual way of grinding the circular portion is to use a chuck-quill and rest, containing a worm and wheel attachment for revolving the work, which is placed on a suitable arbor, but it is not necessary to have the attachment, as the arbor can be turned up in the lathe head, revolving it by operating the draw spindle or any other means that the shop affords.

STEADY REST FOR GRINDING BUSHINGS

Figure 167 shows W. E. Callahan's method of grinding small bushings for drill jigs in the bench lathe. The bushings are first turned and reamed from two to three thousandths smaller than the drill that is to run in them,

then cupped, hardened and lapped to size. Then a hardened piece of drill rod to be used for an arbor is held in the spring collet of the bench lathe and ground a wringing fit with the fingers for the bushing. The object in this method is that they may be absolutely true and also that the slide grinder may be used without interfering with the tailstock. Before starting to grind the arbor, however, a piece of drill rod is passed through the opening in the bed of the lathe, driven into the bence and sprung in such a manner as to exert a gentle pressure on the opposite side from the wheel.

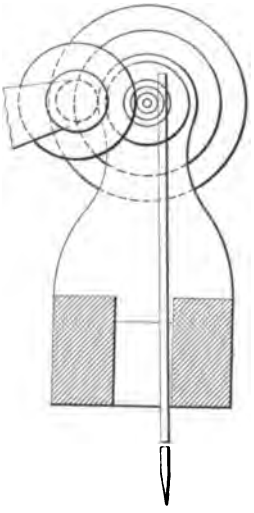


FIG. 167. STEADY REST.

This prevents the chattering and jumping of the wheel which would otherwise occur. When the arbor is ground to size the bushings are wrung on and ground, using the steady-rest as before.

WATCH-LATHE ATTACHMENT FOR GRINDING SMALL STEEL ROLLS

In Figs. 168 and 169, W. H. Brown shows an interesting watch-lathe attachment designed and used by a typewriter concern in New England for grinding small steel rolls.

The emery wheel *A*, which is about 2 in. in diameter and 1/8 in. thick, is clamped to the end of a spindle *B*. This spindle, which is carried by the swinging head *C* works back and forth in the two bearings *D*, which are held in position by screws *E*. On the emery-wheel end of the spindle is keyed a 1 1/4×3/4-in. pulley *F* over which runs a belt from above. Protruding from the upper part of the swinging head *C* and opposite the arm *G* is an arm *H* to which is attached a guard for the emery wheel.

The spindle B is forced in one direction by the end of the vertical arm *K*, which receives its motion from a small roller *L* that contacts with the face of the

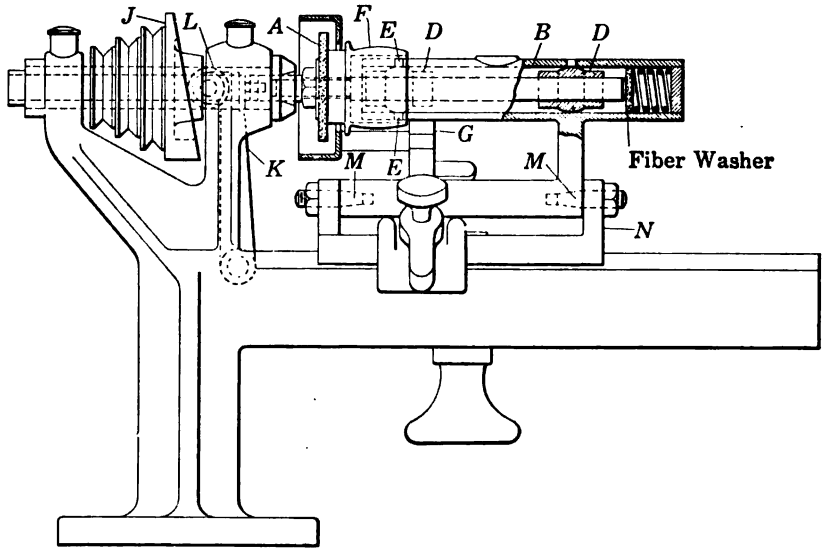


FIG. 168. GRINDING ATTACHMENT FOR WATCH LATHE.

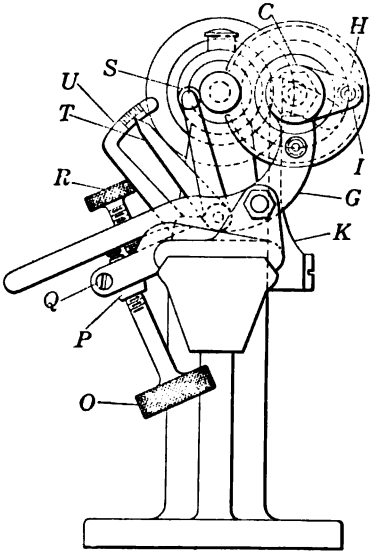


FIG. 169. END VIEW OF LATHE.

cam *J*; it is forced in the opposite direction by a spring inclosed in the end of the swinging head *C*, as shown in the drawing. This reciprocating motion is

limited to 3/8 in., but a greater movement can be had by using another cam *J*.

The swinging head *C*, which pivots on the tapered pins *M* in the ends of the carriage *N*, has its forward position regulated by the adjusting screw *O*, which works in a split arm *P*. When this screw is set in the proper position it is clamped fast by the binding screw *Q*. In the end of the arm *G* that protrudes from the front of the machine is a screw *R*, which not only throws the emery wheel away from the finished roll, but forms means whereby the wheel can be brought into proper position gradually, as needed. Both screws are used in taking up the wear of the emery wheel.

In connection with this machine is an indicator that tells when the roll to be ground is to the correct size. This indicator is fastened to the top of the carriage. One of the indicator arms has a roll *S* on its extreme end that comes against the roll being ground, and another arm T, which is pointed, rides along the face *U*, which is graduated to read in thousandths, the zero mark denoting the exact size of the roll when finished. This indicator can be set to accommodate various sizes of rolls.

MAKING A SLIDE-REST GRINDING ATTACHMENT

Some of the slide-rest grinding attachments used in the bench lathe have the spindle more or less exposed to the wheel dust, and require frequent cleaning while doing work. The outline and details in Fig. 170 are of an attachment built by G. Haessler to meet his own requirements. As most of his work requiring grinding is less than an inch long, it was desirable to have the spindle protected so that when running, no dust could reach any part of it within the bushings.

Referring to the details, it will be seen that the bottom of the base is provided with four lugs, which were milled to fit the T-slot in the slide-rest, thus allowing the attachment to be placed parallel or at right angle to it. The method of boring the hole in the housing proved satisfactory, and is as follows: With the centers in the lathe and the base in position on the slide-rest, a line was scribed across the ends of the boss by operating the cross-feed screw. Then, removing the base it was center-punched and drilled half-way through from each end with a 0.25-in. twist drill. It was next replaced, and the drill with taper shank, shown in the details, was put through, by driving it in a taper chuck and feeding with the slide-rest screw. This was followed by a 0.397-in. reamer, also with taper shank, and driven in the same manner. After the lapping of the hole in the base and bushings, the latter were ground and lapped on the outside, then pressed in lightly.

Although the bushings are sometimes ground to a driving fit, it is preferable to lap them, as this method does away with some lapping after the bushings are in place. In order to protect the spindle as much as possible without weakening

the housing, the housing was cut out as shown, with the hollow mill. The mill was bored slightly back-taper and 0.002 in. larger at the front end than the diameter of the heads of the bushings. The outside of the mill only was ground, to give it a little clearance; then by chucking it in a 0.25-in. collet and holding the base in the hand with one bushing on the center in the tailstock, the bushings were fed into the mill to the proper depth by means of the hand-wheel.

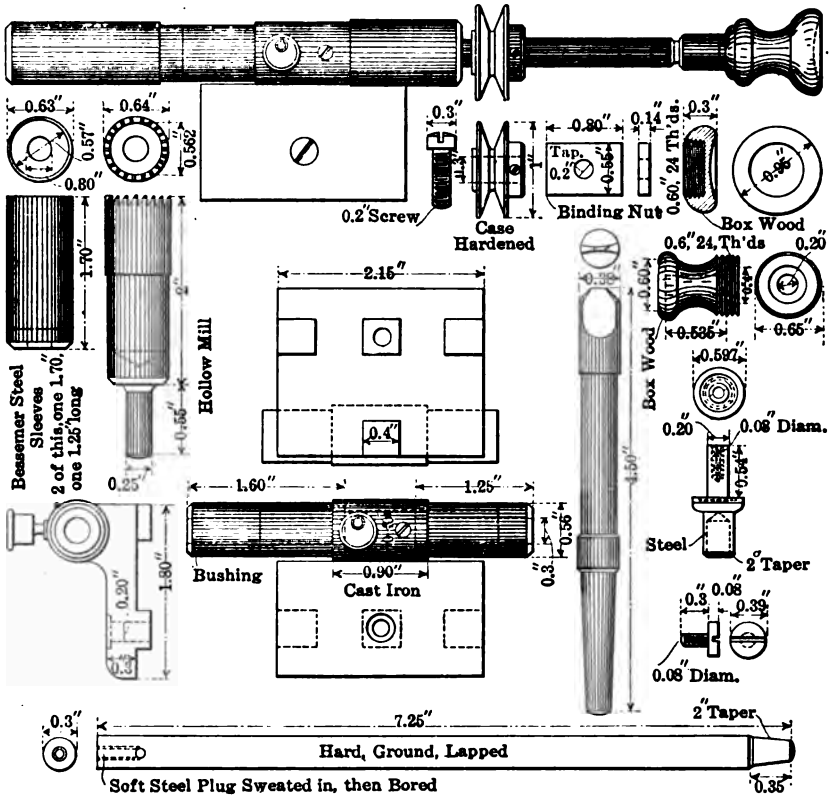


FIG. 170. TRANSVERSE SPINDLE GRINDER.

The 0.30-in. hole in the bessemer-steel sleeves is reamed with the regular reamer, this leaving them just right for a friction fit on the spindle. The front sleeve is seldom removed, while the other may be provided with a small screw in case of wear, due to frequent adjustment. This attachment, unlike some, has two oil holes; to fill the chamber the screw is removed before injecting the oil into the cup. The screw hole acts as a vent for the displacement of air, allowing the oil to enter freely. The spindle was made of Jessop steel, leaving 0.01 in. to grind after hardening. A soft-steel plug was sweated into the spindle, this was bored out for the wheel mount after the spindle was lapped to size. The

boxwood knob, shown in detail, is carried in stock, also the binding nut, and the pulley was made of bessemer steel, case hardened.

A SPHERICAL GRINDING OUTFIT

Figure 171 shows an attachment devised by W. B. Mehl for grinding the spherical surface of a punch. It was necessary to grind the face of the punch spherical,

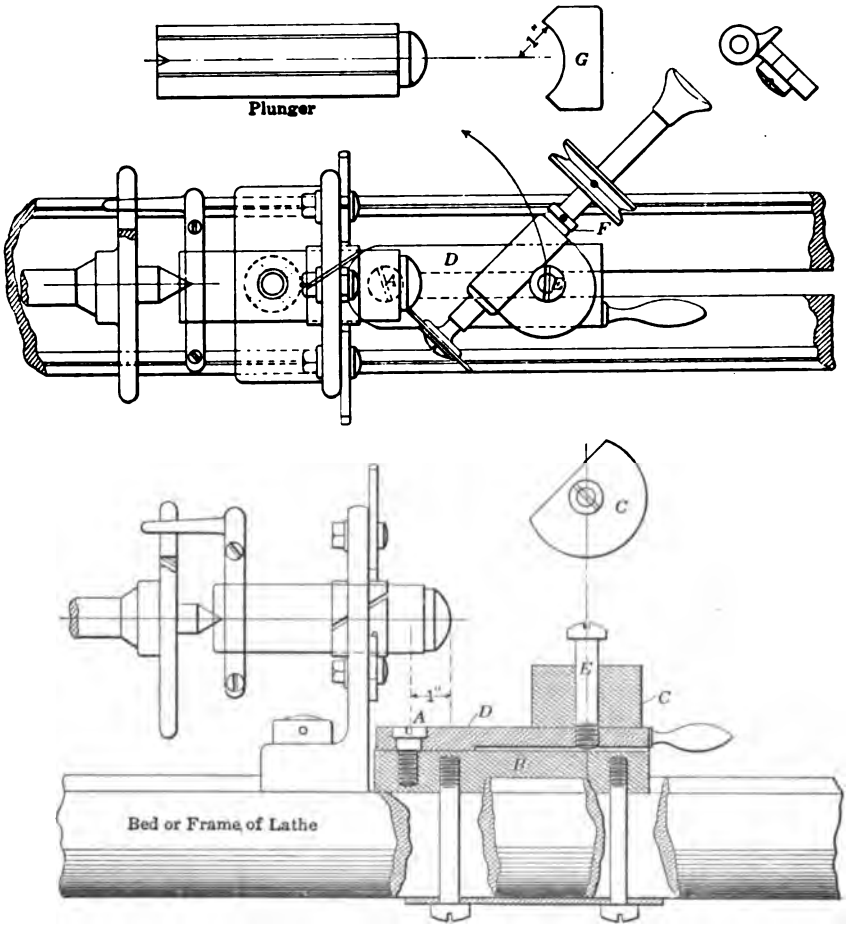


FIG. 171. PLAN, ELEVATION AND SECTION OF SPHERICAL GRINDING RIG.

with a radius of 1 in., with the shedder in place, and after the punch had been fitted to the plunger of the sub-press, and as there was no attachment in the shop for doing it the method here shown was devised. There was available a bench lathe with a steady rest, and therein the plunger was placed ready for grinding. In looking over some fixtures for special jobs a plate with two holes was found,

one threaded and the other counterbored and with a screw in it. This plate was arranged to swivel around screw *A*, which held it to the block *B*, which, in turn, was held to the lathe bed by two screws running up through the central slot in the same. Block *C* was then made of sufficient height to bring the grinding attachment up to the center. This attachment, with block *C*, was held at an angle to plate *D* by screw *E*. This completed the fixture, which was then placed in its right position, or nearly so, by means of a square placed on *D* and brought against the face of the punch at the center, *D* being moved until the center of screw *A* measured 1.01 in. from the face of the punch.

To locate screw *A* central to the plunger a straightedge was held against either side of the lathe bed, which had flatted sides, measurements being taken therefrom and plate *B* shifted until the center of screw *A* came to a central position. The two screws holding plate *B* to the lathe bed were considerably smaller than the slot, which allowed for shifting in locating the attachment. The locating of the attachment as described was not without error, but it was easily and accurately located under working conditions by noting the sparks from the wheel as it moved around the spherical surface, and shifting the fixture as required until the sparks were equal at the extreme points at either side of the center. With this assurance of the fixture's central position, the work was ground to the required diameter by shifting the collar *F* on the grinding spindle for depth of cut until enough had been ground off to have the template *G* fit.

GRINDING SMALL HOLES WITH DIAMOND LAPS[1]

When one suggests the use of diamond powder in the machine shop for the above purpose the reader is apt to pass on believing the cost prohibits its use. First it should be stated that the diamond used for this purpose sells in a varying market from $0.85 to $1 per carat—this is no typographical error, 85 cents to $1. It possesses the same hardness and cutting qualities as the diamond of the gem class selling at $125 per carat, but is not quite so hard as the black diamond used in rock drilling. Diamonds are divided into three principal classes: First, the beautiful white used exclusively for ornamentation; second, the black diamond, selling in the neighborhood of $90 per carat; third, that which we reduce to powder and use as an abrasive, at the modest price of 85 cents per carat. This low price is due to the number of flaws contained, suggesting a shattered condition which latter makes it readily reducible to powder. In color they are varied, the majority gray, then brown, some yellow and a few pinkish. Some are of a good structure but the color is bad. In short, into this class of diamonds are entered all stones which by color, structure and hardness are unfit for the higher classes.

In the grinding of small holes, say from 0.014 to 0.125 in., diamond offers the most economical means obtainable. This, of course, applies to work

[1]W. H. Ebelhare.

ground to accuracy. The sizing of holes in spring chucks made for watch factories and the trade is done with diamond powder. Here we have not an occasional job, but a regular standard product. Undoubtedly men have time and again experimented with diamond powder and discarded its use. In such cases it is believed they either did not use the proper grade of diamond, did not charge the lap properly, or ran at too low a speed.

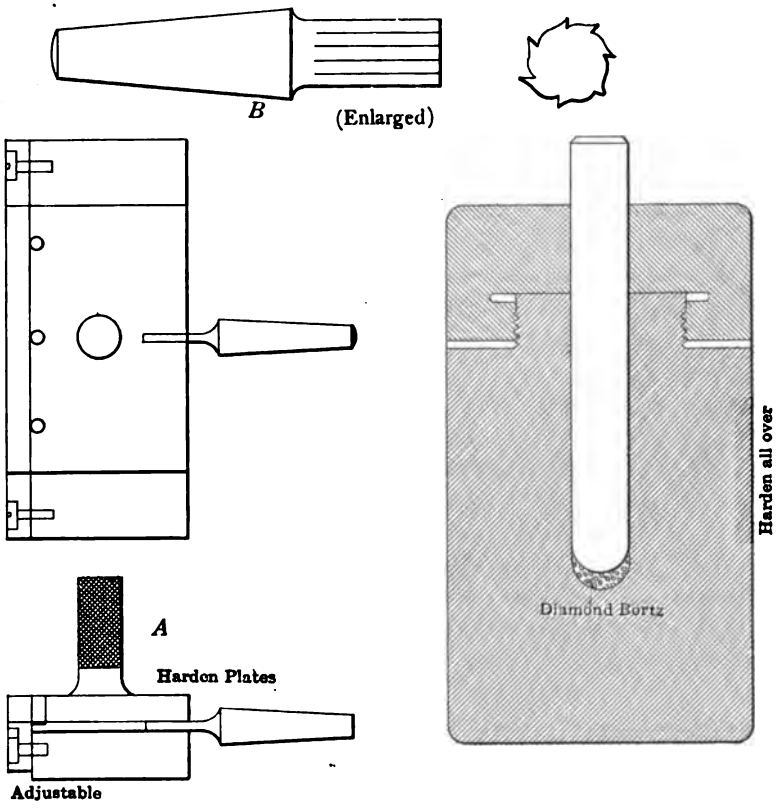


FIG. 172. DIAMOND LAPS, CHARGING PLATES AND CRUSHING MORTAR.

We must acknowledge that the diamond is sufficiently hard and its structure tough enough to withstand the pressure. Laps are charged by two methods, "hammering" and "rolling." The small delicate ones, say from 0.011 to 0.040 in. diameter, are rolled between two plates as shown at *A*, Fig. 172. Diamond No. 3 is placed on the lower plate and is carried to the upper by the lap in the act of rolling. Gentle pressure is all that is necessary for the smaller one but the 0.030 to 0.050 in. sizes will stand considerable more. A small watchmaker's hammer will take care of the larger sizes say from 0.050 to 0.125 in. The lap is supported on a hardened block. The diamond, mixed with a

small quantity of oil to make it adhere, is applied to the lap and block and struck light blows with a small hammer.

The laps are made of soft steel, permitting firm imbedding of the grains in the lap. Tool steel is hard, offering too much resistance. While the latter is stiffer and one is apt to insist on its use for the very small laps, this advantage is offset by the difficulty found in retaining the abrasive. Diamond will cut beautifully if not crowded, and soft steel is well capable of doing the work.

As the laps approach an eighth of an inch and more in diameter the method of setting the grains is the best practice. This is accomplished by supporting the lap on a block of babbitt and with chisel and hammer cutting longitudinal grooves in the lap as in *B*. The more grooves cut the better, and the heavier the bur the more securely the diamond becomes imbedded. Fill the lap with No. 0 or No. 1 diamond as experiment may determine, and hammer on a hardened block. Here the diamond is well supported. The hammering may force the grains under the surface, which is an advantage rather than otherwise. The lap is soft and soon wears down to the diamond which remains supported to the cutting edge. A lap charged in this fashion will cut fast and will throw sparks. It should be emphasized that the proper speed must be maintained. Many mechanics will have a small traverse grinder belted to run say, 18,000 r. p. m., with an emery wheel 2 to 3 in. in diameter, and then drop down to a diameter of 1/8 in. without increasing the speed. This error, of course, is due to thoughtlessness. A lap 1/16 in. diameter should run at a speed no less than 40,000 to 50,000 r. p. m. and care should be taken to see how lightly you can approach your work and do the cutting. The laps when applied to the spindle, naturally run out; the truing can then be done with a small hammer or by any convenient means. Even then one-half is apt to be doing all the work; as this wears away tap the other half into prominence.

The grade of diamond determines the fineness of cut or finish. No. 0 is coarse and cuts fast and naturally leaves a rough finish. Nos. 1, 2 and 3 give a finish in proportion to their finer grains. Experiment must determine the finish you desire. After charging the lap should be washed in a small dish of benzine with vigorous application of a tooth brush, also the rolling plates should be cleaned if you desire to change to a finer grade. After considerable accumulation this benzine can be poured off and the powder washed in clean benzine, this to be poured off after the diamond has precipitated and the latter then allowed to dry. If it does not dry readily, wash again. The process of grading can then be carried through again.

Firms making a constant use of this abrasive always buy it in the bortz and reduce it to powder themselves, thus insuring the best satisfaction both as to quality and grade. The usual method employed is to crush the diamond in a mortar, as shown in *C*, which is drawn to size. The mortar can be held in the lap, or supported on a bench and the plunger struck lightly with a 3/4-lb. hammer, the length of time governed by the force of the blow.

As a first trial, place about one carat in the mortar and strike 25 light blows; then scrape the powder free from the bottom and sides and empty into a receptacle about the size of a tea cup (the latter will do) three-quarters filled with the best olive oil; stir thoroughly and allow precipitation, say for 3 minutes, then pour into another dish, using care, however, not to pour too closely, otherwise you are apt to have a few coarse grains in the finer grade. The residue in the first dish, which we will label No. 0, is held for extremely coarse grinding, or it is washed and repounded. The second dish allow—after stirring—to stand 8 minutes; pour off and label the residue No. 1. Continue according to the following table:

No.
0= 3 minutes precipitation.
1= 8 minutes precipitation.
2=20 minutes precipitation.
3=40 minutes precipitation.
4=1 1/2 hours precipitation.
5=10 hours precipitation.
6=until oil is clear.

Naturally the amount of pounding determines the grade, and the residue is the index to future hammering in powdering. It is rather unsatisfactory to go through the above table with but one carat; 15 to 20 carats or more, is very satisfactory.

Nos. 1, 2 and 3 are used for grinding. Nos. 4, 5 and 6 smeared on boxwood revolving at a good speed give a high degree of polish. No. 4 will be a trifle streaky. No. 6 gives a high, mirror polish. Diamond bortz or diamond powdered can be purchased at jewelers' supply houses.

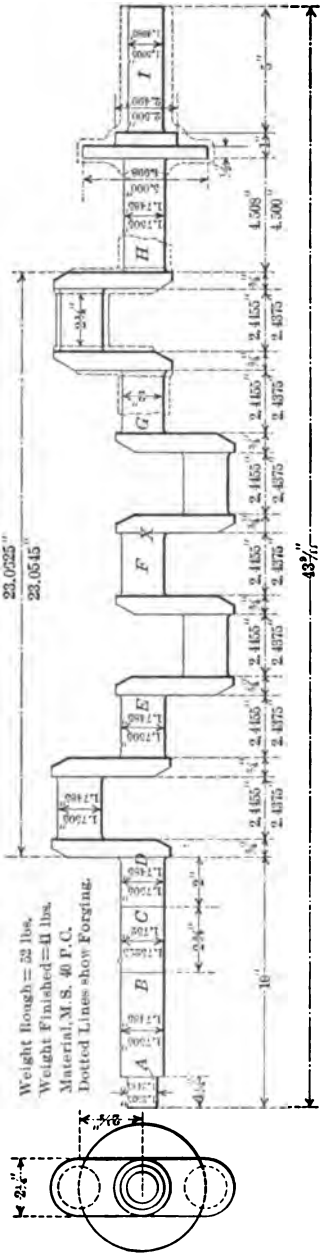


FIG. 173. A FOUR-THROW CRANKSHAFT.

CHAPTER XII

MACHINING CRANKSHAFTS AND OTHER AUTOMOBILE PARTS

In Chapter III on The Field for Grinding, some particulars were given relating to the use of the grinder in machining crankshafts, and the present chapter originally contributed to the *American Machinist* by J. G. Spence, takes up the machining of multiple throw shafts in detail.

The machining of automobile, agricultural machine and other crankshafts with more than one throw or crankpin presents an interesting problem. Since the introduction of drop-forged cranks, the art of finishing them has made wonderful progress. The machining of the crankpins is, of course, the difficult part of the problem. There are at present several methods of doing this work, these methods generally requiring special machines to make the pins. An exception is the method developed by the Norton Grinding Company, Worcester, Mass., within the last few years.

PRELIMINARY OPERATIONS

Figure 173 illustrates a typical four-throw automobile shaft of the so-called "five-bearing" type.

The forging comes from the drop-forger straightened and centered. The first operation is called "turn for cut-off," which means that both ends are turned for a short distance before the forging goes to the cut-off machine. After being cut off to the required length, the shaft is re-

centered in a Hendey-Norton centering machine, which is inspected every day and kept accurate within 0.002 in. This machine grips the shafts by the turned portion, which insures that the new centers will preserve the orginal line of center made by the drop-forger, thus throwing the responsibility of the pins "cleaning out" onto him.

ROUGH-GRINDING THE BEARINGS

The shaft is then taken to a 14×72-in. Norton plain grinder, where the four bearings *E F G H* are rough-ground to 0.035 or 0.040 in. oversize. Bearings *E F G* are ground by bringing forward a wheel with a face 2 1/8 in. wide and using no lateral motion of the work. *H* is ground by bringing the wheel forward twice.

MILLING WEBS AND ROUGH-TURNING FILLETS, ETC.

In the next operation, the right-hand end is rough-turned to 1.535 or 1.540 in. as far as the flange, and the left-hand end is rough-turned to 1.785 or 1.790 in. as far as the first "cheek." This is called "first turn."

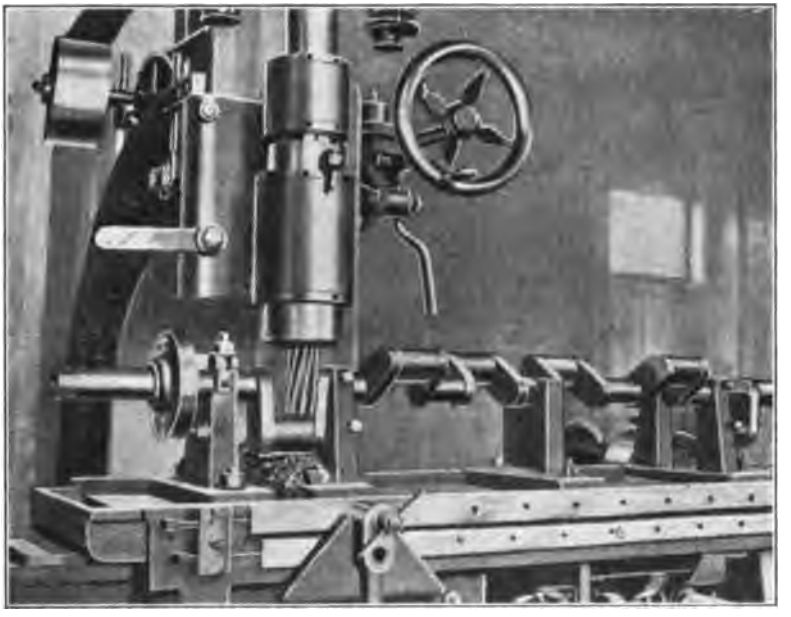


FIG. 174. MILLING CRANKSHAFT WEBS.

Then the shaft is milled on the cheeks or webs. Figure 174 shows a No. 5 Becker-Brainard vertical mill equipped for this operation. The V-blocks are designed to take any automobile shaft. The spacing bars (fastened to the

front of the table) are made for each shaft and are adjustable to allow for sharpening the milling cutter.

After milling, the bearing fillets on *D E F G H* are rough-ground. In this rough-turning, the fillet shoulders are accurately spaced by means of the

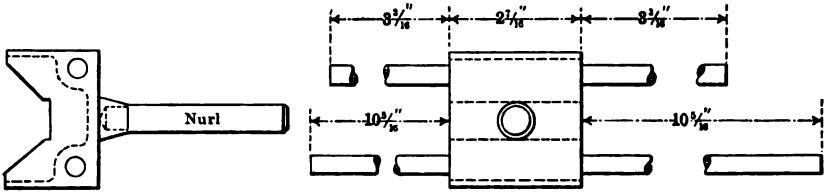


FIG. 175. LENGTH GAGE FOR LOCATING BEARING FILLETS

gage shown in Fig. 175. All distances are taken from the center-bearing fillet nearest the flange. It is marked *X* in Fig. 173.

Next the flange is rough-turned all over, and the shaft is ready to have the

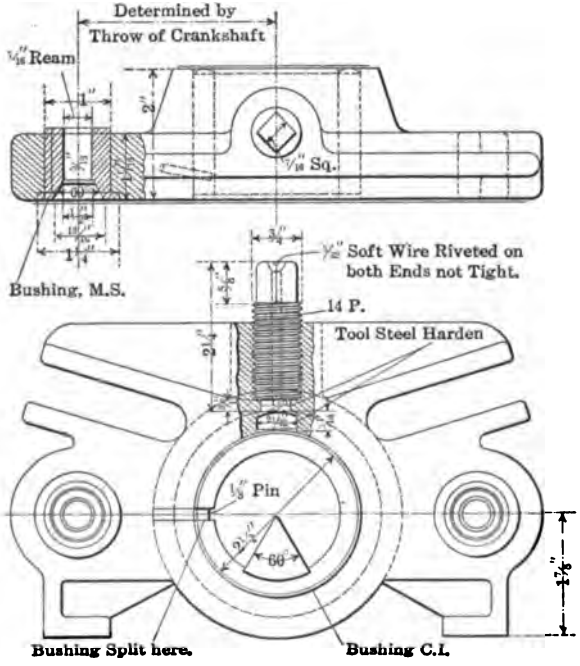


FIG. 176. CENTER BLOCKS FOR CRANKSHAFTS.

ends fitted to the center blocks, shown in Fig. 176. This operation is done in the plate ring used as shown in Fig. 177.

The blocks are then put on a surface grinder by bringing forward a wheel

2 1/4 in. wide. These end fits are made 1.514 to 1.515 in. on the right-hand end and 1.764 to 1.765 in. on the left-hand end.

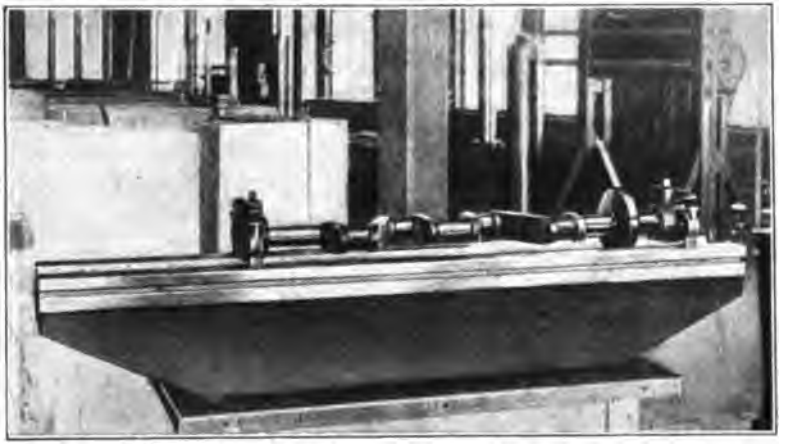


FIG. 177. USE OF THE SURFACE PLATE.

ROUGH-GRINDING THE CRANKPINS

The crank is now ready to have the pins rough-ground. Figure 178 shows a 14×72 Norton grinder set up for grinding crankpins. The rough-grinding is

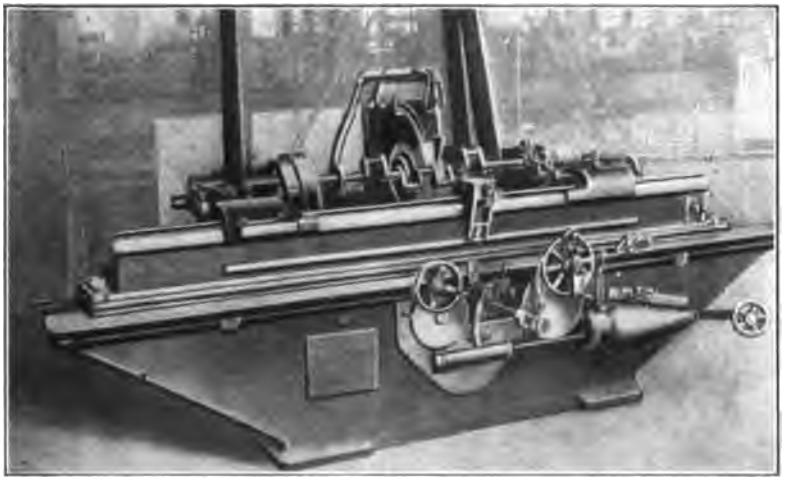


FIG. 178. NORTON GRINDER SET UP FOR CRANKSHAFT WORK.

done by simply bringing forward a wheel of the proper width and using no table traverse whatever. As will be seen in Fig. 173, the rough forging is 1/4 in. larger in diameter than the finished pin. The pin in this particular

shaft is rough-ground to 1.785 or 1.790 in. This operation has been performed on a single pin, time and again, in 2 minutes, and occasionally in as short a time as 40 seconds. This means wheel-time only. Figure 178 illustrates clearly the simplicity of the operation.

FILLETING OPERATION

After all four pins are rough-ground, the shaft is put into an ordinary lathe to have the pin fillets roughed out. The stock is removed by means of the com-

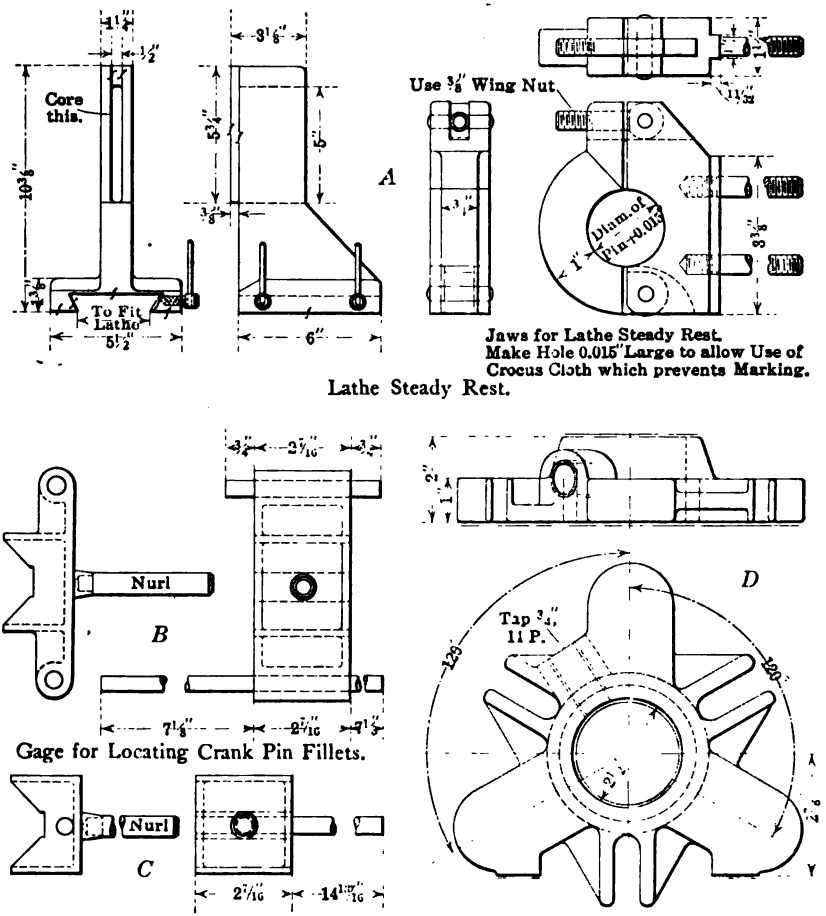


FIG. 179. CRANK GRINDING APPLIANCES.

mon right-hand and left-hand round-nose tool of the proper radius. The pin is held steady by means of the special steady rest at *A*, Fig. 179. The fillet shoulders are accurately placed by the use of the gage *B*, all distances being relative to point *X*, Fig. 173.

The shaft is now straightened, if necessary, and returned to the grinder to have the pins finish-ground. Again, the wheel used has a face wide enough to make the pin without table traverse.

To finish the pin fillets to proper radius the lathe is again resorted to and the pin held steady as in the fillet-roughing operation. This fillet-finishing operation can be done on the grinder, if desired; in fact this is necessary when the shaft is hardened. We have made shafts both ways, although, taking into consideration the extreme accuracy of radius and location of shoulders required by most engine builders, we prefer to use both grinder and lathe.

FINISHING OPERATIONS

After finishing the pin fillets, the center blocks are removed and the shoulder *A*, Fig. 173, is turned down. This is left large up to this time to allow as good a grip for the center block as possible.

The parts *A B C D E F G H I* and both of the flange diameters are then ground to the drawing limits. The fillets on these last-named parts are then finished to correct radius and the flange is squared smooth and to correct dimensions, the location being determined by the gage, *C*, Fig. 179.

After the shaft is inspected for running true and squared to length it is complete.

OTHER SHAFTS

Figure 180 shows a six-throw shaft similar in construction to the four-throw shaft of Fig. 173. This shaft is handled in exactly the same manner. In Fig. 179, *D* gives the style of center block used for the six-throw shaft. Figure 181 illustrates a shaft of the "three-bearing" type. This shaft is of 3 1/2 per cent. nickel steel. The lathe and milling times in Table 29 show the effects of this hard material, but the grinding time is not very much affected. Note the quantity of material removed in order to produce this shaft.

In Fig. 182, *A* shows a shaft designed to avoid all machine work on the webs, while *B* is an example of a very difficult shaft to machine. The cheeks are thin, allowing much spring unless the operator is extremely careful.

SHAFTS FOR AGRICULTURAL MACHINERY

The crankshafts in Fig. 183 are given to bring out the possibilities of the grinder. These shafts are both used in agricultural machinery. They do not need to have a fine finish. This allows the operator to push the work with the one idea of time in his mind. The only operations not done on the grinder are the cutting off and centering and the rough-turning of the ends. The other bearings and the pins are made complete in the grinder. The ends are finish-ground in addition.

SCHEDULE OF TIME REQUIRED TO MACHINE SHAFTS

In Table 29 of operation times, here included, there is a column marked "average time" and one marked "best observed time." The average time is taken from the time cards after the completion of a large number of shafts; the

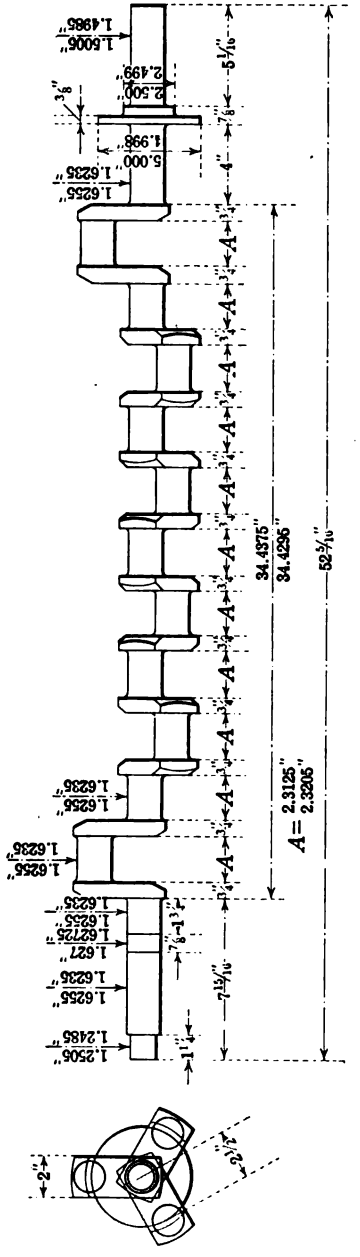


FIG. 180. A SIX-THROW CRANKSHAFT.

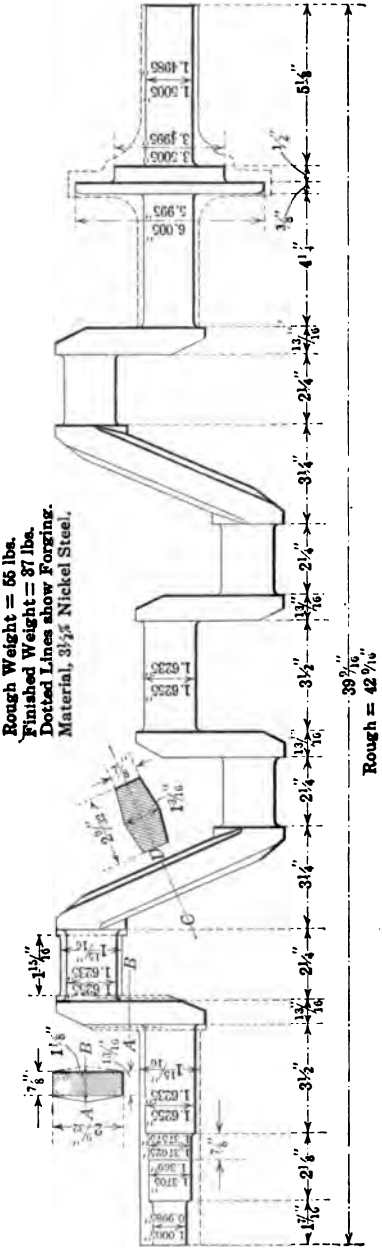


FIG. 181. A NICKEL STEEL CRANKSHAFT.

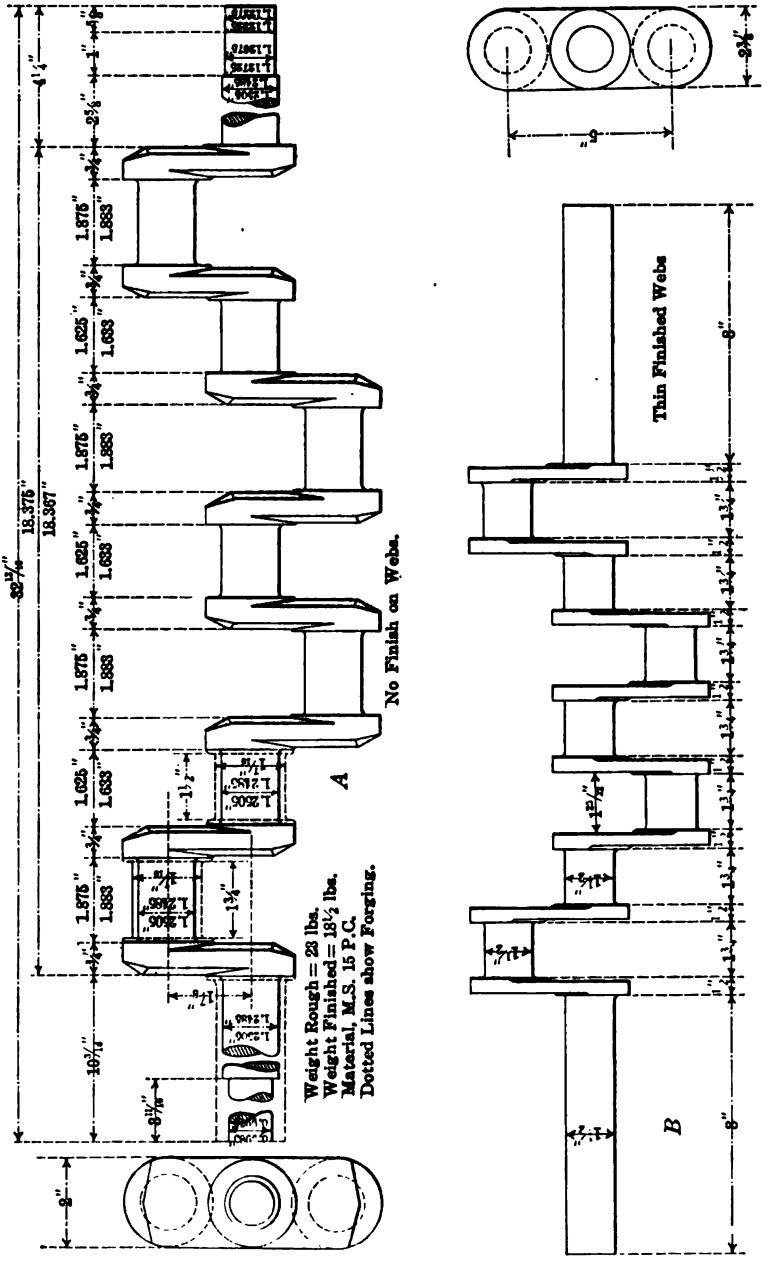


FIG. 182. CRANKSHAFTS WITH AND WITHOUT FINISHED WEBS.

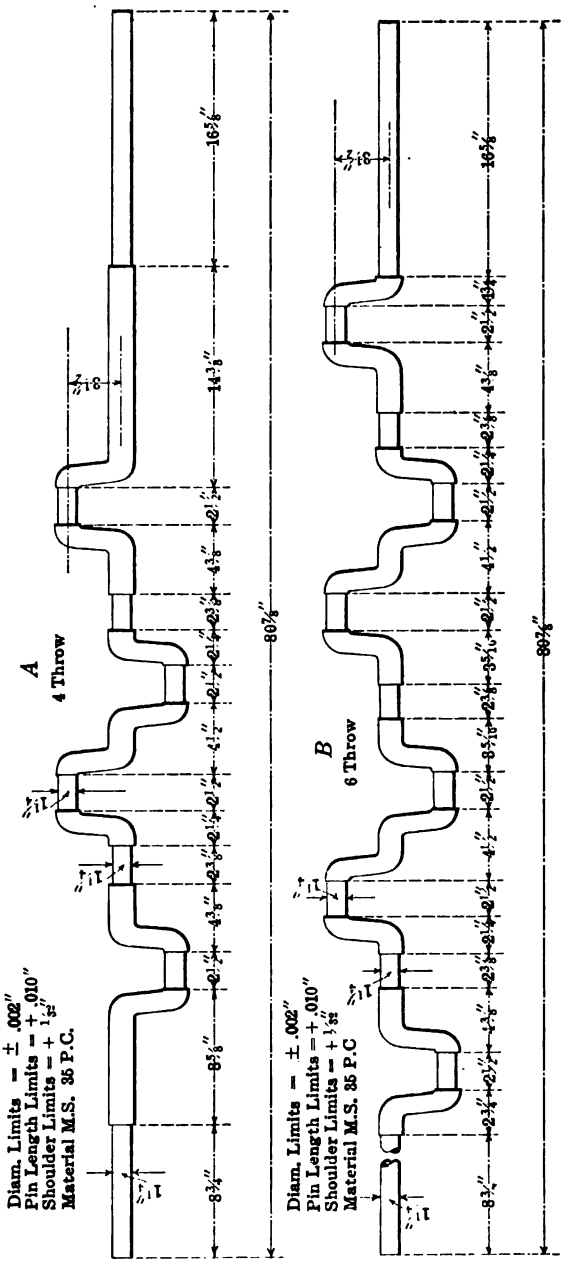


FIG. 183. CRANKSHAFTS FOR AGRICULTURAL MACHINERY.

best observed time was picked up here and there, whenever conditions were favorable.

A separate schedule, Table 30, showing the *average* time taken to produce these shafts is given. Bear in mind that these forgings are almost 7 ft. long and only 1 1/2 in. in diameter. To attempt this job in the lathe would make the reader appreciate the time given in the table.

	Fig. 173		Fig. 180	Fig. 181		Fig. 182-*A*	
	Average time	Best observed time	Average time	Average time	Best observed time	Average time	Best observed time
Turn for cut-off	7	4	12	10	5	6	4
Cut-off and center	8	6	8	8	6	6	5
Rough-grind bearings	36	18	50	28	14	17	15
First-turn ends	17	10	18	17	12	12	8
Mill cheeks	47	30	90	31	22	.....	.....
Rough bearing fillets	65	35	70	60	30	55	30
Rough-turn flanges	36	20	40	48	30	.....	.....
Grind for center blocks	5	3	5	5	3	5	3
Rough-grind pins	31	12	42	36	12	24	10
Rough pin fillets	65	27	70	79	48	72	45
Straighten	20	1	20	20	1	20	1
Finish-grind pins	46	10	50	46	10	37	10
Finish pin fillets	40	15	40	40	15	30	15
Second-turn ends	7	5	12	10	7	12	8
Finish-grind bearings	51	36	70	46	30	42	30
Finish bearing fillets	36	15	40	30	12	30	15
Finish-turn flange	36	20	40	41	25	.....	.....
Square ends to length	7	4	12	8	4	7	4
Total time	560	271	689	563	286	375	203

All time given in minutes and includes handling.

TABLE 29.—TIME REQUIRED FOR VARIOUS OPERATIONS ON CRANKSHAFTS SHOWN IN FIGS. 173, 180, 181 AND 182-*A*.

	A	*B*
Cut off and center	10	10
Grind bearings (except ends)	15	22
Turn ends	15	15
Grind ends	8	8
Grind pins	30	45
Total time	78	100

All time given in minutes and includes handling.

TABLE 30.—AVERAGE TIME REQUIRED TO MACHINE SHAFTS SHOWN IN FIG. 183.

The success of the system which has been described in this chapter and the various features of which are illustrated by the halftone and line engravings depends, like all others, on common sense. An operator who violates natural laws will produce a shaft in which the crankpins are out of line with the bearings and in which the pin fillets are not concentric with the pins themselves. But if he does not spring the shaft by too much pressure from the footstock center and learns the true duty of the backrest on his grinder, he cannot fail to produce correct shafts at small cost.

CRANKSHAFT WORK IN ENGLAND

Some further interesting particulars of crankshaft grinding operations are given by H. Darbyshire as follows, the examples cited being automobile shafts made in England:

FOUR- AND SIX-THROW CRANKSHAFTS

Among the grinding jobs about the Knight engine worthy of special notice are the cranks, both four and six throw; shown in Figs. 184 and 185. These

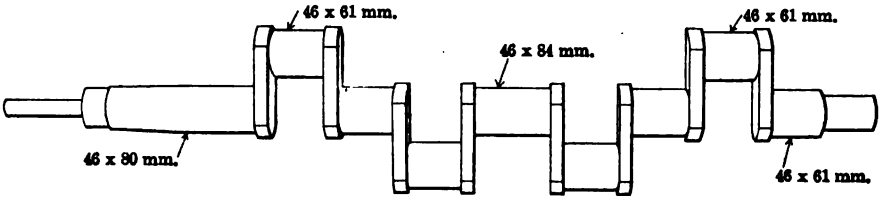


FIG. 184. FOUR-THROW CRANKSHAFT, GROUND IN 3 1/2 HOURS.

are beautiful examples of this class of work and are ground to a very fine limit. In both cases the cranks are ground from slab forgings of nickel steel, the throws being milled out in a Muir crank miller. The six-throw eccentric

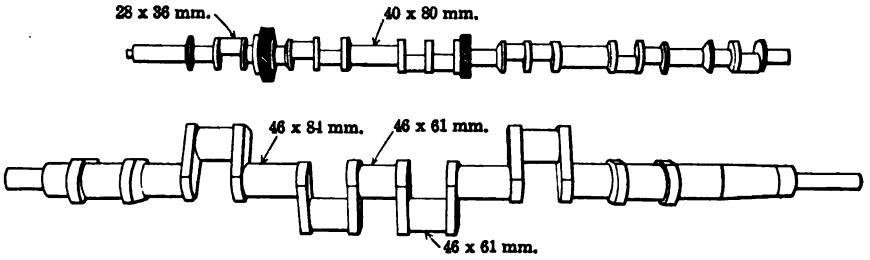
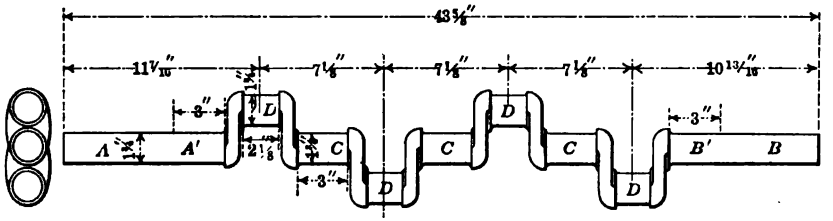


FIG. 185. SIX-THROW ECCENTRIC AND CRANKSHAFTS GROUND IN 2 1/2 AND 5 1/2 HOURS RESPECTIVELY.

shaft shown in Fig. 185 is quite a tricky grinding job but is done in excellent time and to a very fine limit. In the grinding operations, 0.7 mm. is removed from each shaft, Figs. 184 and 185, the tolerance being 0.02 mm. The four-

throw shaft in Fig. 184 is ground in 3 1/2 hours. The larger of the two six-throw shafts in Fig. 185 requires 5 1/2 hours for grinding, the smaller (the eccentric shaft) is ground in 2 1/2 hours, with all the fillets ground to gage. The dimensions of bearings and pins are given in the engravings.

Another shape of crankshaft is shown in Fig. 186. This type of crankshaft is now regularly produced on the Norton machine in an average time of 2 hours



All Pin and Bearing Fillets = 5/16″ Radius

FIG. 186. ANOTHER CRANKSHAFT.

50 minutes. The crankshafts are made from drop forgings and the time given is inclusive of that spent in the lathe for cutting to length, centering and turning the ends for the center bars. Some 4 years ago the total time for the machining of this crank was about 6 hours, but thanks to experience and a few attachments for the grinder, the results noted above are now being obtained.

GRINDING AUTOMOBILE CYLINDERS

Many fail to distinguish between the boring of automobile and other light gas-engine cylinders and those for steam engines, overlooking the added

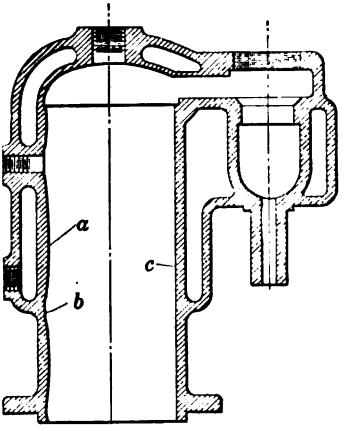


FIG. 187. INEQUALITIES IN AUTOMOBILE CYLINDER.

difficulty due to the extremely thin walls in the case of the lighter engines. With these thin walls the metal springs away from the boring tool where

it is not backed up by connection with the jacket. Port holes also interfere with good boring and hard spots spring away from the boring tool leaving high spots as at *a*, Fig. 187, when they spring back into place. These inequalities must be removed by the grinding wheel.

A soft spot will allow the tool to cut too freely and, if anything, cut below the correct depth (as indicated at *b*), leaving a depression in the walls, each condition being equally disadvantageous.

SPEED OF GRINDING

The speed of grinding cylinders depends on many elements beside the operator, the selection of the grinding wheel being one of the most essential. Cast iron varies to such an extent that makers of the machines carry in stock from 25 to 30 grits and grades so as to have the right wheels for the different varieties of iron in the cylinders. The best way is to try out a number of wheels and see which is best for the iron being used.

In selecting the proper grade of wheel, not only the work but the speed of the wheel and the stiffness of the machine must be considered. A stiff machine allows the use of a softer and freer cutting wheel than a light machine, and stock can be removed much more rapidly and the work be free from chatter marks. This shows why it is not safe to judge of the right wheel, even on the same work, by the wheel that is used on another machine of a different design.

Although a soft wheel wears out faster than a hard one, it does the work in less time so that the lessened labor cost more than overbalances the cost for wheels. The soft wheel will also generally grind a truer hole than a hard wheel as it cuts down the high spots and has less tendency to follow any eccentricity in the cylinder bore.

Too much attention cannot be paid to the proper speed of the wheel as it is much more important than in any other form of machine. A low speed makes a good wheel appear to be too soft.

Cylinders 4 to 4 1/2 in. by 9 in. long can be ground from rough boring in about 15 minutes each, removing 0.01 in. with a limit of 0.0005 in.

GRINDING CYLINDERS HOT OR COLD

The majority of cylinders are probably ground with cold water in the jackets to maintain normal temperature on account of the ease of inspecting after it leaves the grinding machine and before going elsewhere. Others allow the cylinder to heat up as it will and allow a certain amount over the nominal size to allow for shrinkage in cooling. Some use hot water in the jacket to heat the cylinder nearer its working temperature.

There is no question as to the cylinder changing shape when it is hot and theoretically it should be better to have it in this condition when being ground, but it has drawbacks from a manufacturing point of view.

The inspection of cylinders ground hot is not an easy matter and when they are allowed to cool down before inspection, the hole goes out of shape sometimes as much as 0.005 in. This brings up the question as to what the diameter of the hole really is and seems to be one of the main difficulties in the way of grinding cylinders hot.

THE SURFACE LEFT BY THE GRINDING WHEEL

Those who have had much experience with lapping cylinders know that the surface of the iron becomes charged with the abrasive which gets into its pores, and which keeps up the lapping action after the engine is in operation.

Many naturally fear that this is also the case with grinding but chemical analysis, using an acid to eat away the ground surface and then analyzing for abrasive, has failed to find a trace of it.

The action of a vitrified wheel in cutting away stock is entirely different from that of the lapping process and the fact that nearly all spindles of machine tools are ground is very good evidence that they are free from abrasives or they would cut out their bearings. This idea probably originated from a confusion of the old method of rubbing two pieces of iron together with emery and oil between them with the modern method of using a vitrified wheel to cut away stock. The old method undoubtedly charged the metal with emery. But the wheel holds the abrasive with a tenacious bond and the metal is cut away by the many sharp points instead of bedding the abrasive into the metal as in the other case.

TWO METHODS

While there may be said to be two methods of grinding cylinders, first by revolving the cylinder as we do with other internal grinding and second by having the grinding wheel travel around the bore while the cylinder is held stationary, we can practically forget the first method and confine our attention entirely to the last.

With a perfectly symmetrical cylinder there is but little choice as to methods, but with the average cylinder, with its valve chambers and other side outlets and protuberences, the question of getting a running balance of sufficient accuracy to prevent "throwing" the cylinder every revolution, and consequently failing to produce a round hole, puts this method out of the question.

This leaves only the machine of the type shown in Fig. 4, in which the cylinder is bolted or clamped to an angle plate on the carriage of the grinder as in Fig. 188, and the grinding wheel travels around the inside of the cylinder, all the while revolving at its normal speed and cutting the metal as it travels. This does away with all questions of balance.

Unless the cylinder bore is connected with an exhaust system, as it always

should be both for accuracy and for the comfort of the operator, the grinding wheel must run through the combination of metal and abrasive which will collect in the bottom of the cylinder bore. This affects the accuracy of the work and tends to make the wheel glaze as well.

While water can be used direct in this type of machine it is not considered the best practice as then the exhaust system cannot be used to advantage and the wheel must run through the collection of "mud" in the bottom of the cylinder bore.

Where it is thought best to cool the work during the grinding operation it is customary to run water through the cylinder jacket, in the case of a water-cooled engine, or on the outside of the cylinder if there is no water jacket. This does not interfere in the least with the use of the exhaust system.

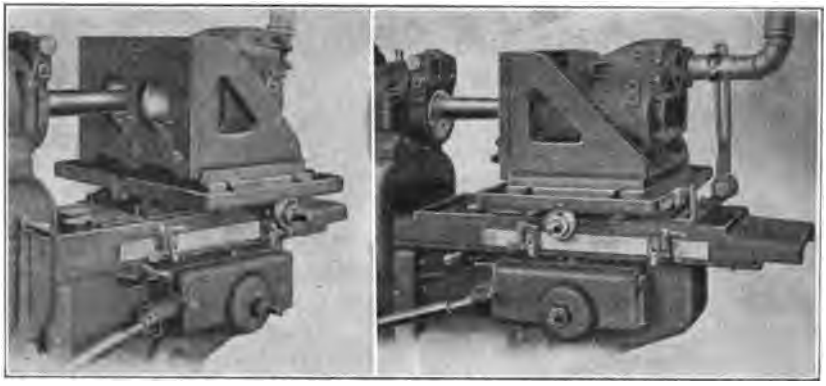


FIG. 188. HOLDING AUTOMOBILE CYLINDERS.

Some engineers who have studied the question carefully feel that it is better not to cool the cylinder in grinding. This is because of the unpreventable unequal expansion under working conditions, owing to the unequal distribution of metal around the cylinder bore. The contention is that it is better to have the cylinder heated up, to the working heat if that were practicable, in order that it may be ground true while distorted to the same shape that it will assume when running.

CYLINDER GRINDING ALLOWANCES

Ideas as to the proper amount to allow for grinding varies widely, but it is coming to be understood that it need be much less than was formerly supposed necessary. This means the allowance for finish grinding where the hole is bored in a good machine or the piece rough turned for grinding.

In internal work, such as gas-engine cylinders, there is no necessity for leaving more than ten one-thousandths of an inch (0.010) in most cases. This

allows ample stock for truing up the hole and decreases the time required for grinding.

AUTOMOBILE PISTON DIAMETERS

The upper end of piston is ground smaller than the back or lower end, on account of the heat of the explosion expanding it more at that end. Common practice seems to be to make the upper end about 0.0025 in. smaller per inch of diameter, than the cylinder. This small diameter usually extends back to the last ring on the front end of the piston. Some make the very front end even smaller than this.

The large diameter of the piston, *i.e.*, the diameter back of the last ring, is usually about one-half the front end allowance less than the cylinder diameter or 0.00125 in. per inch of diameter.

Piston rings are usually given about 0.00025 in. side play in the grooves in the piston.

OVERSIZE STANDARDS FOR PISTONS AND RINGS[1]

Many automobile engines are now made with cylinders cast in pairs, or *en bloc*, and an imperfection in one cylinder bore makes it necessary to throw away cylinders in which the other bores are in perfect condition, in fact, in better condition than any new cylinder which will come from the factory can be, because the old rings and pistons will not usually fit the new cylinder as well, and in any event the new cylinder is comparatively rough, and does not have such an excellent bearing and contact with the rings.

For that reason the ability to refinish a cylinder by the repair man is most desirable and means a considerable saving in time and money to the owner of a car. The advantages of being able to refinish cylinders are not confined to those which have become scored up in running, but apply equally in the case of ordinary wear, which is found in all engines after running 10,000, 20,000 or 30,000 miles.

In this case the refinishing of the cylinders and the substitution of new pistons and rings also means the putting of the engine in first-class condition at a minimum cost.

The refinishing of a cylinder bore can be most easily accomplished by the use of a cylinder grinder, such as have been used for a good many years by almost all the leading concerns in the manufacture of automobile and gas engines.

USING OLD CYLINDERS OF ENLARGED BORE

Occasionally in refinishing a cylinder the scoring is so slight that an increase in diameter of perhaps 0.005 or 0.006 in. only is necessary to produce

[1] James N. Heald, General manager, Heald Machine Company.

a perfect hole. In such cases it is often considered a question whether a new piston is necessary, and frequently customers will decide to use the old pistons, together with a set of rings which are made enough larger to make up for the increased diameter of the bore. Just how much larger the bore can be made than the standard size and have the old piston prove satisfactory to the average user is a debatable question.

When there is much difference in size between piston and cylinder, of course, the opportunity for leakage of gas through the cut in the ring is increased, and it becomes more difficult to maintain compression. It, therefore, seems desirable to make new pistons and rings to secure a quiet running engine when any considerable amount of stock is removed in the refinishing of the cylinder bores.

Experience seems to set the limit of increase in size to 0.005 or 0.006 in. if the old pistons are to be used.

OVERSIZE STANDARDS OF PISTONS AND RINGS DESIRABLE

The adoption and furnishing of certain oversize standards of pistons and rings would be an extremely desirable thing for the manufacturer of engines to arrange. In the first place, the manufacturers have the correct patterns; they have the jigs and equipment to make these pistons and rings correctly and economically and to the proper weight and size, so that the piston pins, bushings, connecting rods, etc., are all interchangeable.

The agent in any town could at very slight expense carry a small stock of these pistons and rings of 0.010, 0.020 or 0.050 in. oversize, according to what standards and how many were adopted. Then is would be easy in the case of a scored cylinder, for the repair man to?

We understand that at the present time the Pierce-Arrow Motor Car Company (and possibly others) is furnishing these oversize standards in 0.010, 0.020 and 0.030 in. large, and that the cost to the customer for a piston and set of rings with pin and screws complete for one cylinder is $5.70 for the four-cylinder, and $6 for the six-cylinder style.

This indicates in the most plain and convincing manner the saving in cost that can be made by this method of handling such repairs; and the gain in time is equally as great and acceptable to the car owner. Another advantage that would accrue to the manufacturers of cars would be in being able to advertise the fact that they were in position to furnish repairs at a moderate cost, and their agents could make repairs if needed at the lowest possible cost.

WHAT THE OVERSIZE STANDARDS SHOULD BE

Experience in regrinding hundreds of cylinders shows that very few cylinders will clean out with less than 0.010 or 0.012 in. of stock removed. When,

however, the scoring is deep and the cylinder shows a great deal of wear 0.025 or 0.030 or even 0.040 in. have sometimes been removed in grinding before a satisfactory surface and hole accurately round and straight can be produced.

It is my impression that two oversize standards would be sufficient in order to reduce the stock that any agent would be obliged to carry, and that 0.015 in. larger for the first oversize standard, and 0.035 or 0.040 in. for the second would really be found ample for all cases and a most satisfactory combination.

The 0.015 increase would be practically 1/64 in. larger than standard, while the 0.040 increase is only 1/25 in. There is no question but that any cylinder in which the walls are of reasonable thickness will stand this amount of increase; in fact, a great deal more, as this amounts to but 1/50 in. on each side.

Piston Ring Allowances

Piston rings are usually made from a "pot" or sleeve, which is generally bored out on the inside, turned on the outside and cut off. They are usually finished by grinding, both on the sides and the outer surface. They are ground on the sides on a ring grinder, the grinding allowance being 0.008 to 0.012 in. and from 35 to 45 rings being ground per hour to within a limit of 0.00025 in. This is for 4 to 5 in. rings of the iron generally used. When the rings are cast separately and the iron is harder, fewer rings will be ground per hour. On 3 to 4 in. rings of the iron used in the turned and bored type, the output is 70 to 75 per hour.

INDIVIDUALLY CAST RINGS

Some builders of automobiles make piston rings differently from the usual way. Instead of casting the rings in a cylinder or pot, as it is usually called,

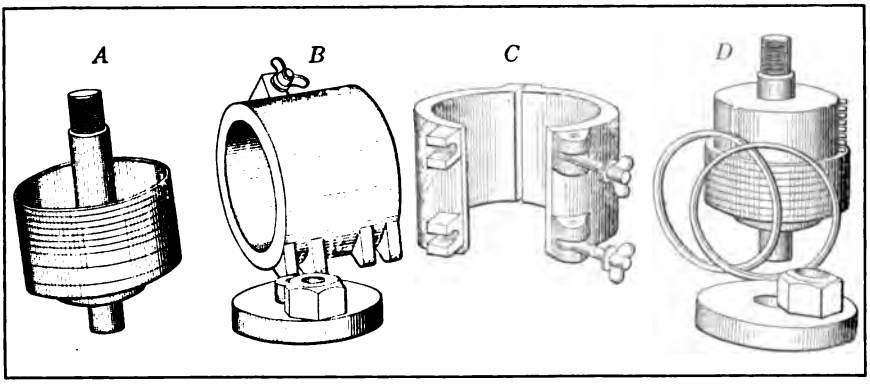


FIG. 189. FIXTURES FOR PISTON RINGS.

each ring is cast separately and finished entirely by grinding. The reason is that in order to have the metal soft enough to turn readily inside and out, it is difficult to secure an iron which has a satisfactory spring, and which will not

take a permanent set. The individually cast rings are extremely stiff and it is impossible to set them, as, while being extremely elastic, they break.

These rings are first rough ground on the sides, slipped over the mandrel shown at *D*, Fig. 189, the heavy side of the ring going to the left and the thin side over the pin shown at the right of the mandrel. They are then rough ground on the outside, and after this the finished grinding is done on the sides.

The next operation is to cut the rings on a hand milling machine in the regular way, and after this they are placed loosely over the mandrel *A* and brought together by being clamped in the fixture shown in *B* and *C*. This is opened and put around the rings, drawing them together and also centering them on the mandrel. They are then clamped firmly in position by tightening up the other flange, and are ready to be ground in the usual way on the outside. The inside of the ring is not machined in any way, and all other operations except cutting are performed by grinding on the machines regularly used in such work.

AN ENGLISH PISTON RING GRINDING FIXTURE

A long experience on this class of work, where several machines were constantly engaged, showed that the greatest rapidity, coupled with accuracy, could be maintained by using a plain mandrel, nicely centered, and run on well-

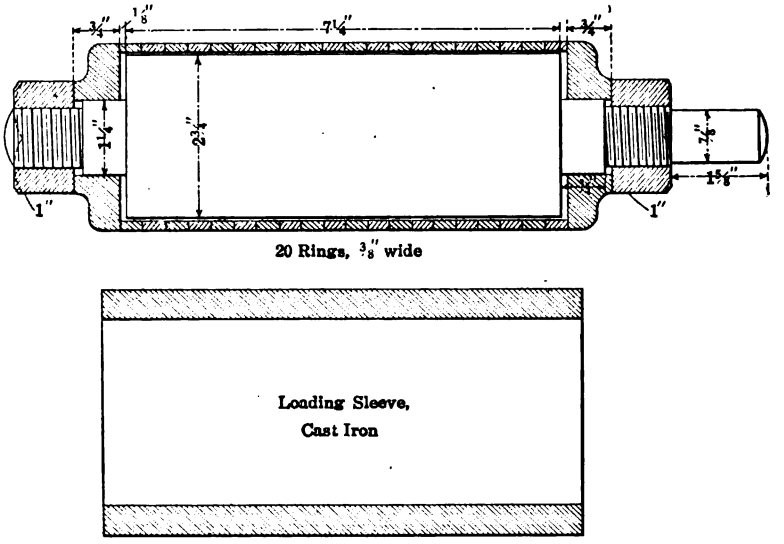


FIG. 190. PISTON-RING GRINDING FIXTURE.

ground centers (a point often not receiving the attention its importance merits), threaded at either end, and having plain end plates, clamped by nuts, as shown in Fig. 190.

The cylinder, of cast iron, is bored and polished to provide a surface on

which rings will slide. The mandrel end plates are turned to fit each size of cylinder. To load, the rings are sprung into the cylinder, with their splits alternately right and left, and the mandrel is inserted with one nut and plate removed, these being then replaced and tightly clamped. A convenient mandrel press having a lead-loaded nose, was used to remove the mandrel from the cylinder, the lead nose preventing the mandrel center being injured.

With this rig the first cost is extremely low, as is also maintenance. One mandrel may be used for a large range of sizes. All plates have standard holes, and the nuts are interchangeable.

Provided all centers are kept in good condition, the mandrel properly adjusted on the centers, and the usual details attended to, accurate work should be readily obtained and maintained.

GRINDING A KEYED SHAFT

One of the latest developments in automobile grinding is shown in Fig. 191, where a machine of the Bath Grinder Company, Fitchburg, Mass., is fin-

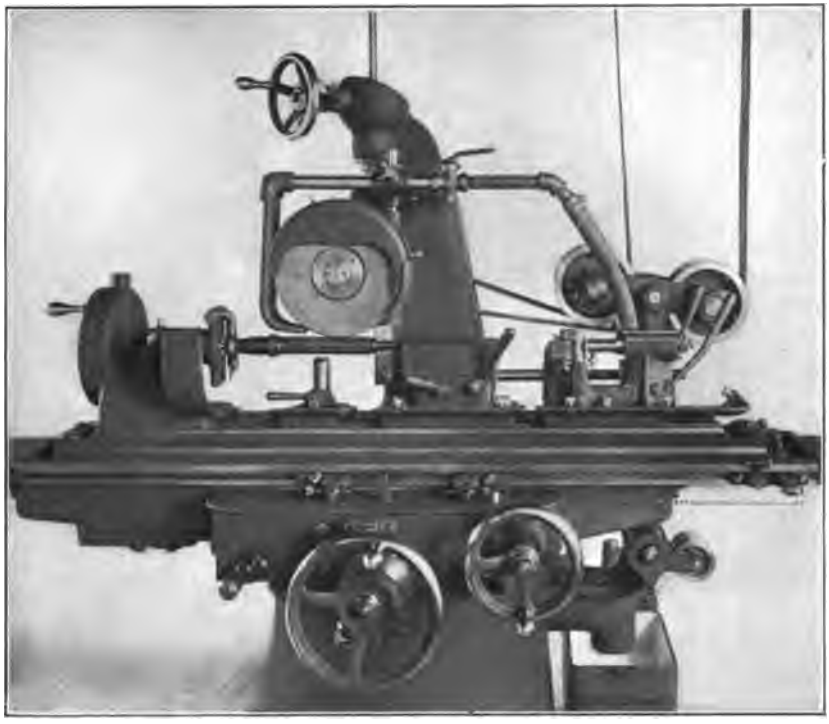


FIG. 191. GRINDING A KEYED SHAFT.

ishing an automobile transmission shaft with solid keys. A formed wheel is used with the face concaved in the center to the arc of the small diameter

of the shaft and the corners beveled to the proper angles for the sides of the keys.

The wheel is kept in shape by the fixture shown in Fig. 192, which carries three diamonds. These are set by the test plug *B* in the block *A*, the two diameters representing the outer edge of keys and the shaft surface between them. The diamond *E* is set to the small diameter and when swung by handle *C* concaves the face of wheel. Diamonds *F* and *G* are set to large diameter of plug and handle *D* moves them past the corners of the wheel at the proper angle. The wheel used has a soft, fairly coarse center and hard, finer grained corners.

FIG. 192. THE WHEEL TRUING FIXTURE.

MISCELLANEOUS OPERATIONS ON AUTOMOBILE PARTS

One job of especial interest shown by Mr. Darbyshire is the machining and grinding of the sleeves in the Knight silent engine as carried out by the Daimler Motor Company of Coventry, England.

Of these sleeves it was formerly thought to be a necessity that they be a very close fit both in the cylinder and within each other so as to prevent the escape of any explosive gases; later practice has shown that this is not necessary but the sleeves are still made to a fine limit to insure interchangeability. The

castings are made of a special fine quality of gray iron and are cast with an extension piece on one end for convenience of chucking. They are first bored and turned on the end to suit the chucking fixture, as shown in Fig. 193, the edge of the bore being chamfered to an angle suitable for the grinding-machine centers. The operations of rough boring and turning are done simultaneously on a turret lathe fitted with a jig chuck, 1.5 mm. being left on the internal

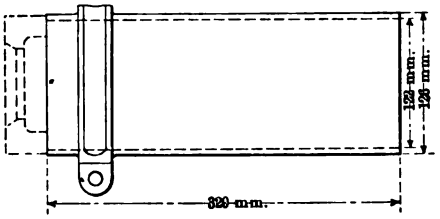


FIG. 193. APPROXIMATE SIZE OF INNER SLEEVE. CHUCKING FACE SHOWN BY DOTTED LINES AT END.

diameter and 1 mm. on the external, for removal by grinding and finish boring; the front end of the hole is also chamfered true with the back edge. The next operation consists of rough grinding the outer diameter which has to be to a fixed size so as to insure its fitting the special fixtures provided for finish boring and grinding; the rough grinding is done in a few minutes on a 10×50-in.

FIG. 194. SLEEVES FOR KNIGHT SILENT ENGINE.

Norton plain grinding machine fitted with revolving centers and using a 24K alundum wheel. The sleeves, after having the extension piece parted off, are now scored for lubrication and the ports and lugs milled out as shown in Fig. 194, they afterward being finish bored; for this purpose they are pushed into a stationary bushing and prevented from turning by having the lug clamped on the end of the bushing. This bushing is inclosed in a tank with a supply of water running constantly through it for cooling purposes, an ordinary cutter

bar is used with supporting bushes at each end and two roughing tools and one finishing tool are used, 0.1 mm. to 0.2 mm. is left in the bore for removal by grinding and the sleeves are bored at the rate of 5 per hour.

SLEEVE GRINDING OPERATIONS

For grinding the bore a special chucking device is fitted to a No. 3 Brown & Sharpe universal grinder work table. This consists of a revolving cylinder, with pulley in the middle, which runs in housings bolted to the table and is driven from the overhead work drum. The sleeves are merely pressed into this cylinder by hand which shows that the previous rough grinding must be done very accurately. A full stream of water is kept running on the grinding wheel and the holes are ground quite straight and to size in some 20 minutes each. The last operation consists in grinding the external diameter, which is accomplished on a 10-in. by 50-in. Norton machine the sleeves being hand pressed on to an ordinary arbor and the grinding being a matter of a few minutes. The point most worthy of note in this job is the cheap production when we consider the accuracy required and obtained, together with the sectional construction; the walls of the bore being very thin necessitate the utmost care in every operation to prevent any springing.

A HOLLOW CAMSHAFT

One or two other automobile grinding jobs may be of interest, or rather the ultimate method adopted in some particular cases for obtaining what was considered the most profitable results by a large continental firm. The hollow

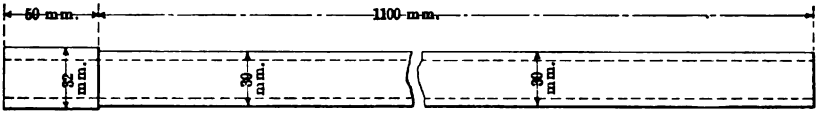


FIG. 195. HOLLOW CAMSHAFT.

camshaft shown in Fig 195 was made from drawn steel tube of 32 mm. diameter: the first place the shafts were turned with two separate chips leaving a grinding allowance of 0.25 mm., the time for this operation was 20 minutes and the time for grinding to a limit of 0.01 mm. was 10 minutes, a total of 30 minutes. At a suggestion, 10 of these shafts were turned with one rough chip, occupying 8 minutes, and a limit of 0.5 mm. allowed in turning; about 0.8 mm. was removed by grinding, this operation taking an average of 16 minutes, or a total of 24 minutes. The method of grinding them right out from the black tubing was also tried, this occupying some 28 minutes to remove the 2 mm. of stock but ultimately the shafts were ground outright from 31-mm. stock in a time which averaged 25 minutes. This method was considered the most economical for

this particular job, some advantage being gained in engaging one machine only in their production and leaving the lathe at liberty for other work. A 10×50-in. Norton machine was used for this work, using a 24L wheel, with a work speed of 35 ft. per minute and a table feed of 8 ft. per minute; five half-round steady shoes were used, spaced equidistantly.

There are scarcely enough data in the job here described to warrant the grinding of black material as a general practice, still it must be remembered that one machine operation was dispensed with and its attendant cost for handling, etc. There is one large machine-tool firm who profess to make large savings per year in this line; they use large quantities of cast-steel bar stock in their automatic plant and a difficulty they found in the ordinary marketable bars was their uneven diameter, this, of course, causing trouble in the automatic gripping of the chuck. They have now for sometime been buying stock 1 mm. over size in 3 meter lengths and rough grinding it to a limit of 0.05 plus and minus; very cheap labor is employed and bars are ground in an average time of 40 minutes. This system they claim more than pays the difference in price of ordinary bars and especially reeled ones.

GRINDING GEAR SHAFTS

With a similar work speed but a 6 ft. per minute table feed, gear shafts like that shown in Fig. 196 were ground in a very accurate and satisfactory manner. These shafts were turned in a turret lathe, the cones being got out with a form tool held in the cross-slide. One wooden shoe was used as a steady rest in grinding and 0.25 mm. of material was removed from the diameter. The time in detail was as follows: For the long part *A*, 60 were ground in 2 hours 40 minutes to a limit of 0.02 mm.; on part *B*, 60 were ground in 64 minutes with

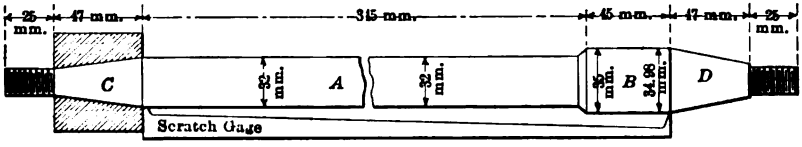


FIG. 196. GEAR SHAFT.

practically no tolerance as they had to be a hand-press fit to a ball-bearing ring; the 60 cones *C* were ground and fitted to ring gage in 3 hours, the same time being consumed in grinding cone *D*. There were gear wheels fitting on these coned ends, the limit for distance being 0.2 mm. The cones *C* were first ground to a ring gage and a ring gage was left on here when they were reversed in the machine. A scratch gage was then used as shown to mark where cone *D* should extend and this cone was ground until the line was split.

An interesting feature of this particular job was that 6 had been turned previously in the engine lathe with rough cuts leaving 0.8 mm. for removal by

grinding and 1 hour 50 minutes was consumed in the 6 shafts; this works out at about 18 minutes each. When the turret lathe was utilized it was found quite safe to leave the finer grinding allowance and the grinding was done in a little over half the time per shaft. It should be said that the time for turning in the engine lathe was 90 minutes per shaft and in the turret lathe 12 minutes each.

CHUCKING PISTONS

For the grinding of automobile and gas-engine pistons there are various ways of chucking them. A method which was adopted proved very efficient and may be worth some little description. The pistons in question were for gas engines of various sizes but a similar rig would, of course, apply to those of a smaller size, as in the automobile trade; all that is necessary is that the mouth

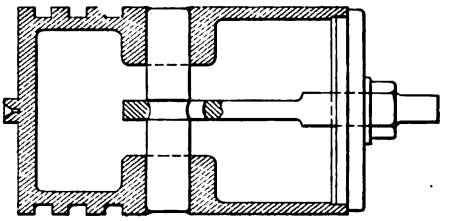


FIG. 197. GAS ENGINE PISTON, SHOWING ARRANGEMENT FOR CHUCKING FOR GRINDING.

of the piston be bored to a fixed size and within reasonable limits. The piston shown in the sketch, Fig. 197, was first machined in a Potter & Johnston semi-automatic, being first held in a chuck by the blind end, the body was turned with two chips leaving 0.025 in. for removal by grinding and the mouth bored to size; it was then reversed and held in a draw-back chuck to have the grooves formed and was faced off to length, leaving a small tit on the end which was centered true with the body. The pistons were then drilled and reamed in a jig to receive the piston pin.

For grinding the piston an arbor was provided in the form of an eye-bolt with hardened center, the arbor was machined as shown to a close fit in the clamping washer and was threaded, the eye of the arbor getting a pull on a pin with a radial groove which was passed through the piston-pin bore. The piston shown was ground in 13 minutes on a Norton 10 × 50-in. grinder. The body of the piston was first ground to size and then each section between the grooves had to be reduced 0.001 in. successively to allow for expansion: It was suggested that 0.010 to 0.015 only be left for removal by grinding in future as the turning came out very accurate and if this suggestion has been acted on the grinding time would easily be reduced to about one-half.

The wheel used was a 24J+ alundum, running at a speed of 6000 ft. per minute, the work speed was about 38 ft. per minute. Heavy roughing cuts were

taken up to the last 0.002 in. of material, the wheel was then trued up and a few finishing chips taken.

GRINDING HARDENED STEEL RINGS

Some hundreds of hardened rings were wanted which were to serve as gear-case liners for roller bearings. They were of the shape shown at *A* Fig. 198 and had to be very accurate, and interchangeable. The outer diameter was to be a press fit in the gear case and the holes had all to be duplicated on account of the rollers. The rings were made from lengths of annealed steel tubing of a size which allowed of 1/16 in. of material being removed from the outer diameter and the bore. These tubes were fed through the hollow spindle of a turret lathe and the rings were turned and bored leaving 0.010 in. for grinding both

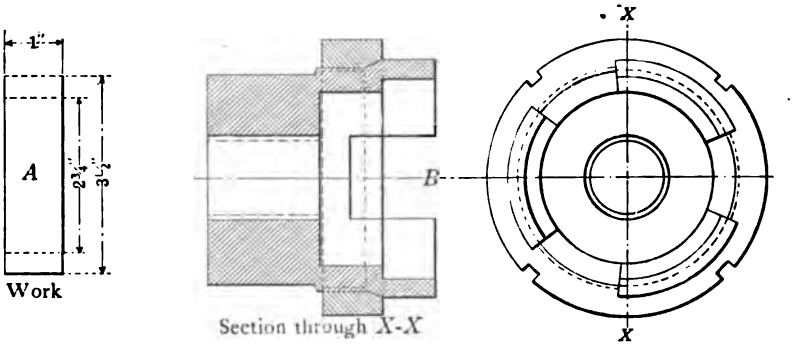


FIG. 198. ADJUSTABLE SPRING CHUCK FOR GRINDING RINGS INTERNALLY.

internally and externally. The corners were then rounded and the rings cut off 0.010 in. over finished length, the rings then had a second annealing and were afterward carbonized and hardened in the usual manner. It should be stated that this second annealing was found necessary owing to some scrap being made in the first batch that went through; owing to the want of annealing many of the rings had distorted so much in hardening that they would not clean up to size. The first grinding operation was to finish both ends to length, and for this purpose a Pratt & Whitney vertical-spindle machine was used. A number of the rings were first cleaned up on one end, and after these were all completed they were reversed on the chuck and the opposite end ground to length, the wheel being fed down to a dead stop; an alundum cup wheel of 30-grit grade K was used and the time occupied to grind the two ends was 35 seconds. Early experience had taught that even with the two annealings the rings were liable to go out of shape a little when the hard outer surface was ground so that two operations of roughing and finishing were resorted to.

ROUGHING AND FINISHING OPERATION

Rough grinding internally was the next operation and for this purpose an adjustable spring chuck, shown at *B*, Fig. 198, was fitted to the universal head of a Brown & Sharpe grinder, a No. 8 Brown & Sharpe internal fixture was used with a wheel of 36-grit grade K, and the holes were rough ground to within about 0.004 in. of finished size, 7 minutes being consumed in the operation.

The rings were now strung on a parallel arbor which held ten rings and were held fast by a nut and washer while being ground. A 10×50-in. Norton machine was used carrying a 24J wheel and the ten rings were roughed down to 3.503 in. in 13 minutes including the setting. The rings were now allowed a day or two to season and were then placed on the same arbor and finished externally; any of those which had gone oval were eased off in the bore by means of a small wheel fixed on the bench grinding stand until they passed a free fit on the arbor, they were ground to a limit of 0.00025 in. + and − the time occupied being 16 minutes for the ten rings including setting. The same wheel was used as for roughing but it was nicely trued up. The last operation was finishing the bore, and for this a spring chuck was used similar to that for rough grinding but a 60-grit J wheel was employed. The holes were finish ground in 10 minutes to a limit of 0.00025 in. over size. A full stream of water was used in all grinding operations.

THE ADJUSTABLE SPRING CHUCK

This adjustable spring chuck is a very useful and reliable tool for any work of this description and has a distinct advantage over the ordinary universal chuck. Any practical grinder hand knows from experience that jobs like the one described may be ground O. K. to gages in the ordinary self-centering chuck, but the work is of a different shape when released from the chuck, this more especially if the grinding is done dry and the work allowed to become only moderately warm. In the chuck of collar illustrated the adjusting nut is so regulated as to give just sufficient tension to prevent the work from slipping, while the holding segments are elastic enough to allow for any change of size or shape while the grinding operation is in progress. If at times they become slightly out of truth the nut can be closed down and a chip taken down the bore with the chuck in position in the machine. These chucks are easily and cheaply made from gray iron and for work of a lighter type they may be made with a taper shank to fit the center hole of the grinding-machine spindle instead of screwing direct on the spindle nose. It is just possible that in smaller sizes the segments would require relieving a little to reduce the springing tension which is, of course, a matter of experiment for any particular size of job.

HOLDING GEARS FOR GRINDING

One of the many problems which have been brought out by the development of automobile manufacture, is the method of holding gears for grinding after hardening, so that the hole may be ground concentric with the pitch line of the gear teeth. The problem is to hold the gear from some point or points which had a definite and fixed relation to the gear teeth when they were cut. If the outside of the gear blank were absolutely true with its axis of rotation on the gear cutter, the gear could easily be chucked from the outside by simply dividing up any inequalities as to roundness which the gear had undergone during the hardening process. Or, if the milling cutter be formed so as to cut the outer ends of the teeth at the same time it is finishing the curved tooth space, this method could be easily used.

In a similar way we can use the bottoms of the teeth perhaps more easily than in any other way, provided the finishing cutter goes clear to the bottom. But as the bottom of the tooth is merely for clearance, many gear men let the

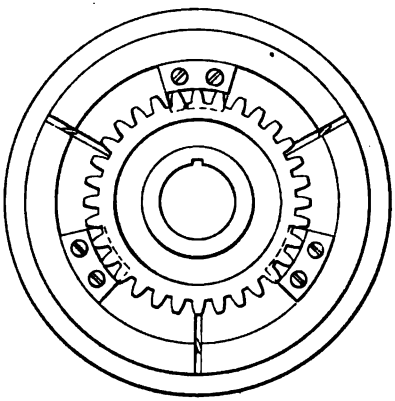


FIG. 199. DETAIL FOR OUTSIDE HOLDING CHUCK.

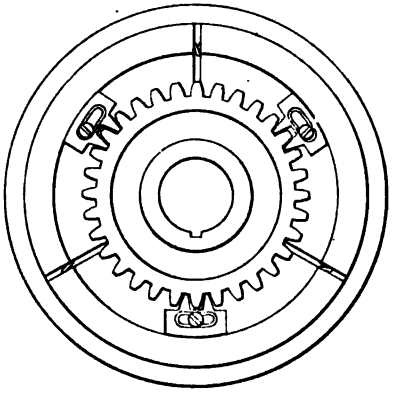


FIG. 200. DETAIL OF BOTTOM HOLDING CHUCK.

roughing or stocking cutter go deeper than the finishing cutter, so as to save the latter as much work as possible. Where this is done, it is not much safer to depend on the bottom of the teeth than on the outside, and it becomes necessary to hold gears by their curved faces, whether at the exact pitch line or not it is not so important.

Figures 199 to 202 show the three methods which have been mentioned in connection with the use of draw-in chucks, as made by the Heald Machine Co. Figure 199 requires no explanation whatever, as it is shown in detail in Fig. 2 In Fig. 200, where the gear is held by the points of the jaws reaching to the bottom of the teeth, the same general principle prevails, except that the jaws are free to move in the direction of the slot, so as to accommodate gears of approximately the same diameter, although having different numbers of teeth.

Figure 201 shows a somewhat similar arrangement, the difference being that the holding portion of the jaw consists of a hardened-steel roll, which fits in between the teeth at approximately the pitch line and holds them from this point. This is known as pitch-line control.

One advantage of the method of root control is that the chuck jaws bear directly on solid metal in a straight line with the web of the gear, and that it is a very simple matter to maintain the accuracy of the contact point by simply truing them with a grinding wheel whenever it may become necessary.

The use of five jaws has been suggested and tried in some cases, with the

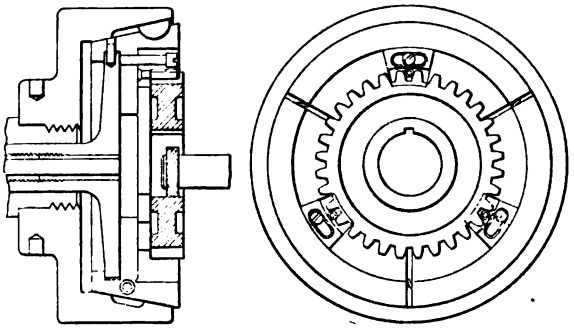


FIG. 201. DETAIL OF PITCH LINE CONTROL.

idea of securing still greater accuracy, but the results obtained by using three jaws are so far ahead of the work usually secured in the average shop, that the three-jaw chuck is recommended for general use.

A NEW CHUCK WITH DOUBLE ROLLS

Working along this line, the Heald company has developed a new chuck, using pitch-line control, and at the same time securing greater accuracy than heretofore when rollers were used. As will be seen from Fig. 202, each jaw carries two hardened-steel rollers having conical ends, and being held by loosely fitted conical recesses, which allow perfect freedom to the rolls *R*, and at the same time prevent them dropping out of place, unless the retaining plate *P* is removed. These rolls fit in between the teeth of the gear to be ground, adjusting themselves easily to any inequalities of the tooth surface, and seating against hardened-steel plates, which are inserted in the collet jaws when they are drawn down into place to hold the gear for grinding.

This method gives great latitude in the holding of gears by their curved faces, and in allowing for any distortion which may occur in hardening of the gears. It also allows the jaws to be maintained with great accuracy, as by removing the retaining plate *P*, and taking out the rolls, the hardened-steel plates, against which they bear, can be easily ground to remove any inaccuracy

due to either wear or distortion, although the latter is hardly possible in a chuck of this description.

The general appearance of these chucks in use can be easily seen from the halftone illustration.

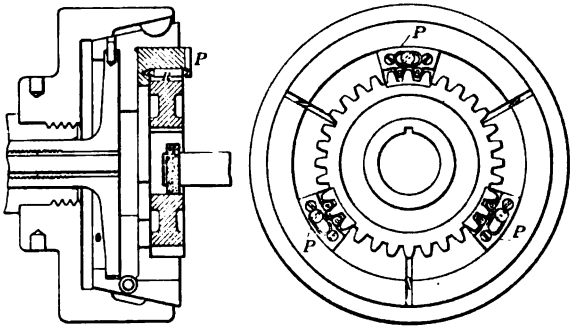


FIG. 202. DETAIL OF DOUBLE ROLL JAW.

The latest development in holding gears by this method is shown in Fig. 203. This is simply a modification of the double-roller chuck, in which the two hardened rolls are spread so as to skip one tooth space.

This secures the double advantage of distributing the holding points more

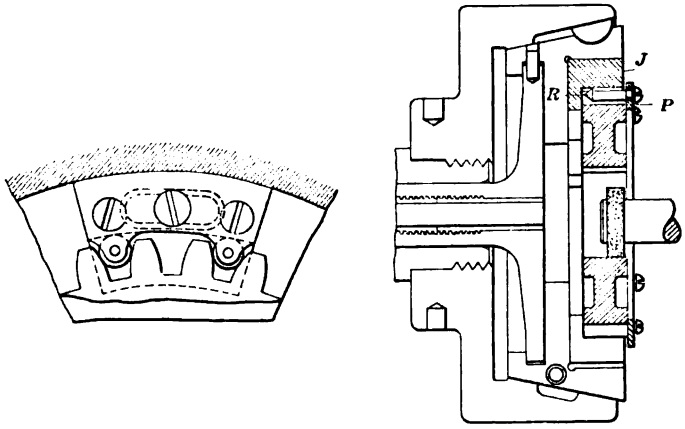


FIG. 203. HOLDING BY ALTERNATE TEETH.

equally around the gear and of taking care of any distortion of the gear teeth which occurred in hardening. One of the most noticeable effects of this distortion is to produce a wide and a narrow space next to each other. This arrangement skips the wide or the narrow space, as the case may be, and is much more apt to hold the gear by spaces having approximately uniform width.

A NINE-POINT CHUCK

A still further modification of this idea is shown in Fig. 204, in which each of the three holding jaws carries three hardened steel rolls, placed far enough apart to fit in every third tooth space. This gives largely increased contact all around the gear, and in the case of gears which have become elliptical in hardening should give a more accurate chucking by dividing up their inaccuracy.

It will also be seen that the hardened steel rolls are held in a different manner than in either of the other chucks. These rolls are mounted in a retaining ring, so as to hang loosely by the neck under the head, and are perfectly free to

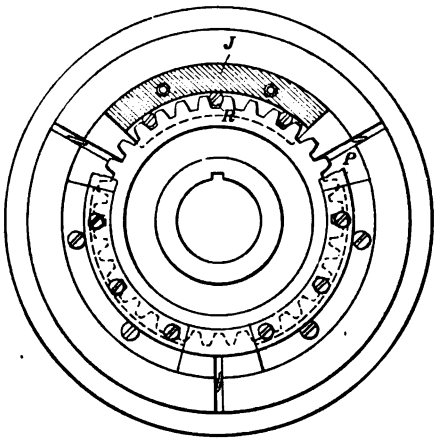


FIG. 204. NINE-POINT CHUCK.

adjust themselves between the curved spaces of the gear teeth and the backing surface of the hardened steel jaws, which form a part of the draw-in chuck. The retaining ring carrying the roll is entirely independent of the chuck, and comes out with the gear. To use, it is simply slipped over the gear to be ground, and the whole thing inserted in the chuck. This makes it very easy to keep both the rolls and the hardened steel jaws perfectly clean and tends to increase the accuracy obtained.

HOLDING BEVEL PINIONS AND GEARS

Perhaps bevel pinions and gears give more trouble than spur gears, owing to the increased difficulty of holding the inclined surfaces so as to revolve truly both with regard to diameter and length. Figure 205 shows a form of chuck for holding bevel pinions by the bottom of the teeth. The only difference between this and the spur-gear chuck is the use of a single-pointed holding jaw, which is not adjustable and which is ground to the proper angle to hold the gear to be ground.

It will be noticed in the section view that the bearing surface is relieved in

the center and also that there is a projection lip, which comes down on the out side of the gear and prevents any tendency to slip outward.

Holding devices for bevel gears have also been made to include rollers in a similar manner as for spur gears, but they are more or less complicated, and the plain jaws shown have proved very satisfactory on bevel pionions in most cases.

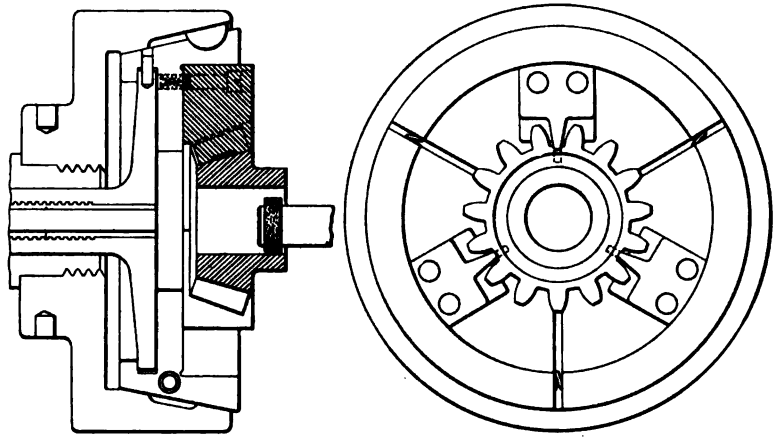


FIG. 205. HOLDING SMALL BEVEL GEARS.

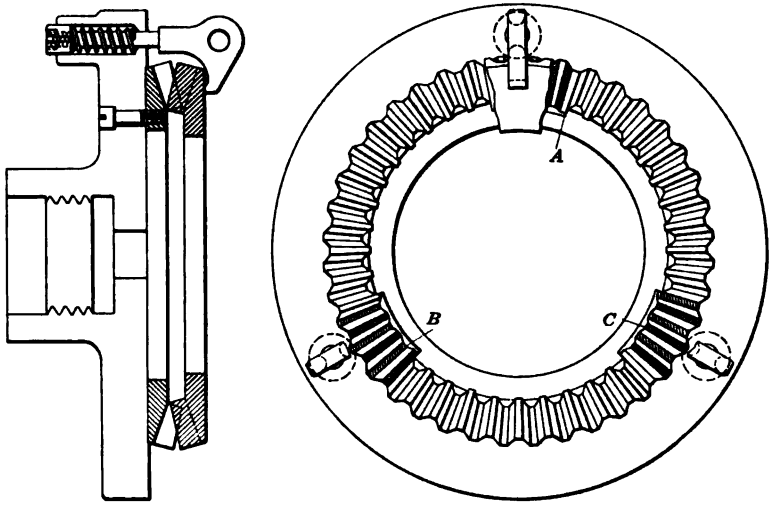


FIG. 206. HOLDING LARGE BEVEL GEARS.

A NEAT CENTERING DEVICE

When it comes to holding large bevel gears, such as are used in the drives for automobiles, the method shown in Fig. 206 has been found very satisfactory and can easily be adopted in any shop.

One of the gears themselves is selected and about three-quarters of the inner points on the teeth are cut away so as to leave three points containing three or four teeth each, as can be seen at *A*, *B* and *C*, in Fig. 206. This holding gear is then fastened permanently and accurately to the face-plate and forms the centering and driving device for all gears on this size and kind which are to be ground. It is only necessary to place the gear to be ground so that the teeth will fit the teeth which have been allowed to remain and project from the holding gear, and these accurately center any gear put in mesh with them. As they also form a positive drive, it is only necessary to hold the gear to be ground in contact with these teeth by the spring-controlled hook bolt shown, to hold the work in place during the grinding operation. This makes a very simple and accurate method of holding work of this kind.

Should this master gear wear, new contact surfaces can be secured by grinding back the high teeth which have been left, and the original accuracy restored.

CHUCKS FOR PLAIN WORK

To show the draw-in construction, as applied to all work to be ground, one of the chucks for cylindrical work is shown in Fig. 207. The body *B* screws

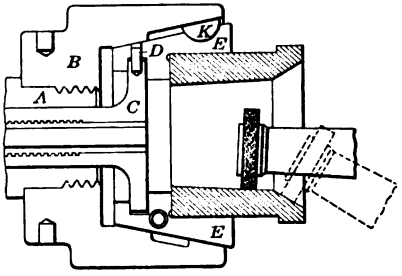


FIG. 207. CHUCK FOR PLAIN WORK.

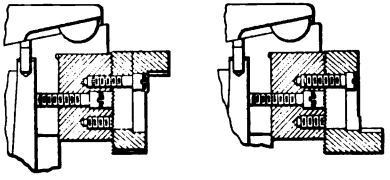


FIG. 208. CHUCK WITH ADJUSTABLE JAWS.

on the work spindle *A*, the draw-in sleeve *C*, running through this and controlling the jaw *E*, both by the flange on the sleeve and the pin *D*. A Wood-

ruff key K is sunk into the jaw and slides in a keyway in the body B, to prevent the jaws turning under any strain whatever.

Where a variety of sizes of gears are to be ground and where the quantity is not sufficient to warrant having special chucks for each size, chucks having adjustable jaws are recommended, as is shown in Fig. 208. Bv moving the screw which holds the false jaw from one hole to the other and utilizing the slot in the false jaw, work can be held from 5/8 in. to 8 1/8 in. in diameter, which gives a very wide range. By omitting the adjustable jaws and putting in jaws for either root or pitch-line control, this collet chuck is very convenient.

The methods shown are the latest practice recommended by the Heald Machine Co., and should prove of value to those having internal grinding to be done.

CHAPTER XIII

GRINDING REAMERS, CUTTERS AND OTHER TOOLS

Some years ago the Cincinnati Milling Machine Company made an extensive series of experiments to determine the proper clearances for reamers. From the data thus obtained they compiled tables for four styles of reamers, for obtaining what they considered the best clearances, the object being to grind a clearance which should enable the reamer to ream the greatest number of smooth holes with a minimum of wear. The four styles of reamers referred to are as follows: Hand reamers for steel, hand reamers for gray iron and bronze, chucking reamers for gray iron and bronze, chucking reamers for steel. This company uses adjustable blade reamers almost exclusively all of which are ground in the tool room on the Cincinnati cutter and tool grinder.

HAND AND CHUCKING REAMER CLEARANCES

Figure 209 is a cross-section of a hand reamer. Two clearance lines, *A* and *B*, are ground on the blades, *a* being the cutting clearance and *b* the second clear-

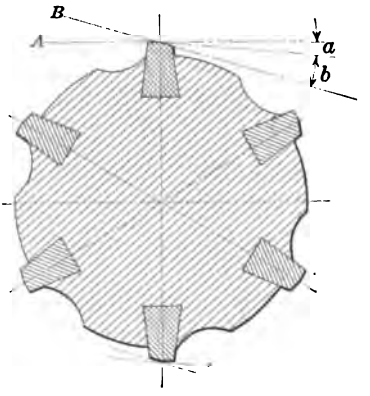


FIG. 209. CROSS-SECTION THROUGH HAND REAMER.

ance called for in the table. The object of giving the adjustment for the second clearance so minutely is to provide a proper width of land, which equals 0.025 in. on all hand reamers for gray iron or bronze, and 0.005 in. on hand reamers for steel.

Chucking reamers for gray iron and bronze have, in this system, 23 degrees beveled ends as shown at *A*, Fig. 210, and are provided with two clearances along the blades, for which the settings are given in Table 31. The beveled ends have only one clearance which is equal to the second clearance given in Table 31. The cut at *B* shows a chucking reamer for reaming steel. In these reamers the blades are circular ground to the exact size of hole to be reamed and without clearance, the 45-degree beveled ends only having clearance as given in section 4 of Table 31. On all reamers of this style the blades are ground from 0.015 to 0.020 in. below size half of their length toward the shank end.

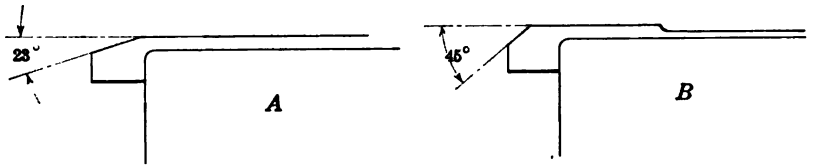


FIG. 210. REAMER BLADES.

REAMER CLEARANCE TABLE

Grind with cup wheel 3-in. diameter; mount tooth rest on emery-wheel head set work centers above tooth rest the amount given below in sections 1, 2, 3 and 4 of Table 31. Set tooth rest below work centers amount given below in section 4.

In grinding the clearances for the various kinds of reamers as given in Table 31, Sections 1, 2 and 3, the tooth rest is held stationary on the grinding wheel head of the grinder, while in grinding the 45-degree beveled ends on the chucking reamers for steel the tooth rest is supported from the grinder table and travels with the work. The front ends of the hand reamer blades are tapered about .004 per inch. The back ends of the blades are also slightly tapered to prevent injuring the holes when backing out the reamer.

	SECTION 1 Hand reamer for steel. Land of cutting clearance .006 wide		SECTION 2 Hand reamer for cast iron and bronze. Land of cutting clearance .025 wide		SECTION 3 Chucking reamer for cast iron and bronze. Land of cutting clearance .025 wide		SECTION 4 Chucking reamers for steel, circular ground. Angle of end of blade 45 degrees
Size of reamer	Vertical adjustment for cutting clearance	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance on angle
$\frac{1}{2}$ in.	.012 in.	.052 in.	.032 in.	.072 in.	.040 in.	.080 in.	.080 in.
$\frac{9}{16}$ in.	.012 in.	.057 in.	.032 in.	.072 in.	.040 in.	.080 in.	.080 in.
$\frac{5}{8}$ in.	.012 in.	.062 in.	.032 in.	.072 in.	.040 in.	.090 in.	.090 in.
$\frac{11}{16}$ in.	.012 in.	.067 in.	.035 in.	.095 in.	.040 in.	.100 in.	.100 in.
$\frac{3}{4}$ in.	.012 in.	.072 in.	.035 in.	.095 in.	.040 in.	.100 in.	.100 in.
$\frac{13}{16}$ in.	.012 in.	.077 in.	.037 in.	.095 in.	.045 in.	.125 in.	.125 in.
$\frac{7}{8}$ in.	.012 in.	.082 in.	.040 in.	.120 in.	.045 in.	.125 in.	.125 in.
$\frac{15}{16}$ in.	.012 in.	.087 in.	.040 in.	.120 in.	.045 in.	.125 in.	.125 in.
1 in.	.012 in.	.092 in.	.040 in.	.120 in.	.045 in.	.125 in.	.125 in.
$1\frac{1}{16}$ in.	.012 in.	.097 in.	.040 in.	.120 in.	.045 in.	.125 in.	.125 in.
$1\frac{1}{8}$ in.	.012 in.	.102 in.	.040 in.	.120 in.	.045 in.	.125 in.	.125 in.
$1\frac{3}{16}$ in.	.012 in.	.106 in.	.042 in.	.122 in.	.045 in.	.125 in.	.125 in.
$1\frac{1}{4}$ in.	.012 in.	.112 in.	.045 in.	.145 in.	.050 in.	.160 in.	.160 in.
$1\frac{5}{16}$ in.	.012 in.	.118 in.	.045 in.	.145 in.	.050 in.	.160 in.	.160 in.
$1\frac{3}{8}$ in.	.012 in.	.122 in.	.045 in.	.145 in.	.050 in.	.160 in.	.175 in.
$1\frac{7}{16}$ in.	.012 in.	.127 in.	.045 in.	.145 in.	.055 in.	.175 in.	.175 in.
$1\frac{1}{2}$ in.	.012 in.	.132 in.	.048 in.	.168 in.	.055 in.	.175 in.	.175 in.
$1\frac{9}{16}$ in.	.012 in.	.137 in.	.050 in.	.170 in.	.055 in.	.175 in.	.175 in.
$1\frac{5}{8}$ in.	.012 in.	.142 in.	.050 in.	.170 in.	.060 in.	.200 in.	.200 in.
$1\frac{11}{16}$ in.	.012 in.	.147 in.	.050 in.	.170 in.	.060 in.	.200 in.	.200 in.
$1\frac{3}{4}$ in.	.012 in.	.152 in.	.052 in.	.192 in.	.060 in.	.200 in.	.200 in.
$1\frac{13}{16}$ in.	.012 in.	.157 in.	.052 in.	.192 in.	.060 in.	.200 in.	.200 in.
$1\frac{7}{8}$ in.	.012 in.	.162 in.	.056 in.	.196 in.	.060 in.	.200 in.	.200 in.
$1\frac{15}{16}$ in.	.012 in.	.167 in.	.056 in.	.196 in.	.064 in.	.200 in.	.200 in.
	Mount tooth rest on emery wheel head.						Mount tooth rest on table of machine.

TABLE 31.—REAMER CLEARANCES

	SECTION 1 Hand reamer for steel. Land of cutting clearance .006 wide		SECTION 2 Hand reamer for cast iron and bronze. Land of cutting clearance .025 wide		SECTION 3 Chucking reamer for cast iron and bronze. Land of cutting clearance .025 wide		SECTION 4 Chucking reamers for steel, circular ground. Angle of end of blade 45 degrees
Size of reamer	Vertical adjustment for cutting clearanc	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance on angle
2 in.	.012 in.	.172 in.	.056 in.	.216 in.	.064 in.	.224 in.	.225 in.
2 1/16 in.	.012 in.	.172 in.	.056 in.	.216 in.	.064 in.	.224 in.	.225 in.
2 1/8 in.	.012 in.	.172 in.	.059 in.	.219 in.	.064 in.	.224 in.	.225 in.
2 3/16 in.	.012 in.	.172 in.	.059 in.	.219 in.	.064 in.	.224 in.	.225 in.
2 1/4 in.	.012 in.	.172 in.	.063 in.	.223 in.	.064 in.	.224 in.	.225 in.
2 5/16 in.	.012 in.	.172 in.	.063 in.	.223 in.	.064 in.	.224 in.	.225 in.
2 3/8 in.	.012 in.	.172 in.	.063 in.	.223 in.	.068 in.	.228 in.	.230 in.
2 7/16 in.	.012 in.	.172 in.	.063 in.	.223 in.	.068 in.	.228 in.	.230 in.
2 1/2 in.	.012 in.	.172 in.	.065 in.	.225 in.	.072 in.	.232 in.	.230 in.
2 9/16 in.	.012 in.	.172 in.	.065 in.	.225 in.	.072 in.	.232 in.	.230 in.
2 5/8 in.	.012 in.	.172 in.	.065 in.	.225 in.	.075 in.	.235 in.	.235 in.
2 11/16 in.	.012 in.	.172 in.	.065 in.	.225 in.	.075 in.	.235 in.	.235 in.
2 3/4 in.	.012 in.	.172 in.	.065 in.	.225 in.	.077 in.	.237 in.	.240 in.
2 13/16 in.	.012 in.	.172 in.	.065 in.	.225 in.	.077 in.	.237 in.	.240 in.
2 7/8 in.	.012 in.	.172 in.	.070 in.	.230 in.	.080 in.	.240 in.	.240 in.
2 15/16 in.	.012 in.	.172 in.	.070 in.	.230 in.	.080 in.	.240 in.	.240 in.
3 in.	.012 in.	.172 in.	.072 in.	.232 in.	.080 in.	.240 in.	.240 in.
3 1/16 in.	.012 in.	.172 in.	.072 in.	.232 in.	.080 in.	.240 in.	.240 in.
3 1/8 in.	.012 in.	.172 in.	.075 in.	.235 in.	.083 in.	.240 in.	.240 in.
3 3/16 in.	.012 in.	.172 in.	.075 in.	.235 in.	.083 in.	.243 in.	.240 in.
3 1/4 in.	.012 in.	.172 in.	.078 in.	.238 in.	.083 in.	.243 in.	.245 in.
3 5/16 in.	.012 in.	.172 in.	.078 in.	.238 in.	.087 in.	.243 in.	.245 in.
3 3/8 in.	.012 in.	.172 in.	.081 in.	.241 in.	.087 in.	.247 in.	.245 in.
3 7/16 in.	.012 in.	.172 in.	.081 in.	.241 in.	.090 in.	.247 in.	.245 in.
	Mount tooth rest on emery wheel head						Mount tooth rest on table of machine.

TABLE 31.—REAMER CLEARANCES—*Continued*

Size of reamer	SECTION 1 Hand reamer for steel. Land of cutting clearance .006 wide		SECTION 2 Hand reamer for cast iron and bronze. Land of cutting clearance .025 wide		SECTION 3 Chucking reamer for cast iron and bronze. Land of cutting clearance .025 wide		SECTION 4 Chucking reamers for steel, circular ground. Angle of end of blade 45 degrees
	Vertical adjustment for cutting clearance	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance	Vertical adjustment for second clearance	Vertical adjustment for cutting clearance on angle
3 1/2 in.	.012 in.	.172 in.	.084 in.	.244 in.	.090 in.	.250 in.	.250 in.
3 5/8 in.	.012 in.	.172 in.	.084 in.	.244 in.	.090 in.	.250 in.	.250 in.
3 3/4 in.	.012 in.	.172 in.	.087 in.	.247 in.	.093 in.	.253 in.	.250 in.
3 13/16 in.	.012 in.	.172 in.	.087 in.	.247 in.	.093 in.	.253 in.	.250 in.
3 7/8 in.	.012 in.	.172 in.	.090 in.	.250 in.	.097 in.	.257 in.	.255 in.
3 15/16 in.	.012 in.	.172 in.	.090 in.	.250 in.	.097 in.	.257 in.	.255 in.
3 1/2 in.	.012 in.	.172 in.	.093 in.	.253 in.	.100 in.	.260 in.	.255 in.
3 15/16 in.	.012 in.	.172 in.	.093 in.	.253 in.	.100 in.	.260 in.	.255 in.
4 in.	.012 in.	.172 in.	.096 in.	.256 in.	.104 in.	.264 in.	.260 in.
4 1/16 in.	.012 in.	.172 in.	.096 in.	.256 in.	.104 in.	.264 in.	.260 in.
4 1/8 in.	.012 in.	.172 in.	.096 in.	.256 in.	.104 in.	.264 in.	.260 in.
4 3/16 in.	.012 in.	.172 in.	.096 in.	.256 in.	.106 in.	.266 in.	.260 in.
4 1/4 in.	.012 in.	.172 in.	.096 in.	.256 in.	.106 in.	.266 in.	.265 in.
4 5/16 in.	.012 in.	.172 in.	.096 in.	.256 in.	.106 in.	.266 in.	.265 in.
4 3/8 in.	.012 in.	.172 in.	.096 in.	.256 in.	.108 in.	.268 in.	.265 in.
4 7/16 in.	.012 in.	.172 in.	.096 in.	.256 in.	.108 in.	.268 in.	.265 in.
4 1/2 in.	.012 in.	.172 in.	.100 in.	.260 in.	.108 in.	.268 in.	.265 in.
4 5/8 in.	.012 in.	.172 in.	.100 in.	.260 in.	.108 in.	.268 in.	.265 in.
4 11/16 in.	.012 in.	.172 in.	.100 in.	.260 in.	.110 in.	.270 in.	.270 in.
4 3/4 in.	.012 in.	.172 in.	.100 in.	.260 in.	.110 in	.270 in.	.270 in.
4 13/16 in.	.012 in.	.172 in.	.104 in.	.264 in.	.114 in.	.274 in.	.275 in.
4 7/8 in.	.012 in.	.172 in.	.104 in.	.264 in.	.114 in.	.274 in.	.275 in.
4 15/16 in.	.012 in.	.172 in.	.106 in.	.266 in.	.116 in.	.276 in.	.275 in.
5 in.	.012 in.	.172 in.	.106 in.	.266 in.	.116 in.	.276 in.	.275 in.
5 1/8 in.	.012 in	.172 in.	.110 in.	.270 in.	.118 in.	.278 in.	.275 in.
			.118 in.	.278 in.			
	Mount tooth rest on emery wheel head						Mount tooth rest on table of machine

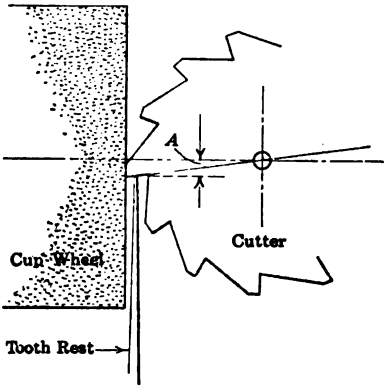
TABLE 31.—REAMER CLEARANCES—*Continued*

CUTTER CLEARANCE TABLES

Tables 32 and 33 give settings for obtaining 5 degrees and 7 degrees clearance on cutter teeth when grinding with cup and disk wheels. When the cup wheel is used the tooth rest is set below the work centers an amount equal to *A* in Table 32. When a disk wheel is used the work centers and tooth rest are both set below the center of the wheel according to distances *B* in Table 33.

CUP WHEEL CLEARANCE TABLE

For setting tooth rest to obtain 5 degrees or 7 degrees clearance when grinding peripheral teeth of milling cutters with cup-shaped wheel.



Diameter of cutter, inches	For 5° clearance, *A* =	For 7° clearance, *A* =
¼	.011 = 1–64 −	.015 = 1–64
⅜	.015 = 1–64	.022 = 1–64 +
½	.022 = 1–64 +	.030 = 1–32
⅝	.028 = 1–32 −	.037 = 1–32 +
¾	.033 = 1–32	.045 = 3–64
⅞	.037 = 1–32 +	.052 = 3–64 +
1	.044 = 3–64	.060 = 1–16
1⅛	.050 = 3–64 +	.067 = 1–16 +
1¼	.055 = 1–16 −	.075 = 5–64
1½	.066 = 1–16	.090 = 3–32
1¾	.077 = 5–64	.105 = 7–64
2	.088 = 3–32 −	.120 = 1–8
2¼	.099 = 3–32 +	.135 = 9–64
2½	.110 = 7–64	.150 = 5–32
2¾	.121 = 1–8	.165 = 11–64
3	.132 = 1–8 +	.180 = 3–16
3¼	.143 = 9–64	.195 = 13–64
3½	.154 = 5–32	.210 = 7–32 −
3¾	.165 = 5–32 +	.225 = 7–32 +

TABLE 32.—CUP WHEEL CLEARANCE

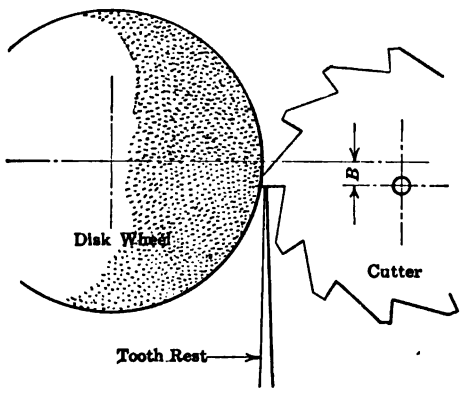
Diameter of cutter, inches	For 5° clearance, A =	For 7° clearance A =
4	.176 = 11–64	.240 = 15–64
4½	.187 = 3–16	.255 = 1–4
4½	.198 = 13–64 −	.270 = 17–64
4¾	.209 = 13–64 +	.285 = 9–32
5	.220 = 7–32	.300 = 19–64
5¼	.231 = 15–64	.315 = 5–16
5½	.242 = 1–4 −	.330 = 21–64
5¾	.253 = 1–4	.345 = 11–32
6	.264 = 17–64	.360 = 23–64
6½	.286 = 9–32	.390 = 25–64
7	.308 = 5–16	.420 = 27–64
7½	.330 = 21–64	.450 = 29–64
8	.352 = 23–64	.480 = 31–64
8½	.374 = 3–8	.510 = 33–64 −
9	.396 = 25–64 +	540 = 35–64 −
9½	.418 = 27–64 −	.570 = 37–64 −
10	.440 = 7–16 +	.600 = 19–32 +
10½	.462 = 15–32 +	.630 = 5–8 +
11	.484 = 31–64	.660 = 21–32 +
11½	.506 = 1–2 +	.690 = 11–16 +
12	.528 = 17–32 +	.720 = 23–32 +
12½	.550 = 35–64 +	.750 = 3–4
13	.572 = 37–64 −	.780 = 25–32 −
13½	.594 = 19–32 +	.810 = 13–16 −
14	.616 = 5–8 −	.840 = 27–32 −

TABLE 32.—CUP WHEEL CLEARANCE—*Continued.*

DISK WHEEL CLEARANCE

Giving distance *B* for setting work centers and tooth rest below center of wheel spindle to obtain 5 degrees or 7 degrees clearance with wheels of different diameters when grinding with periphery of disk wheel.

Some interesting applications of the different forms of wheels to the grinding of cutters and other tools on the Cincinnati cutter grinder are illustrated in Figs. 211 to 223. These views will be found instructive, particularly in showing the proper way of presenting the work to the grinding wheels and also as illustrating the special advantages of the different shapes of wheels for operating upon given surfaces.



Diameter of grinding wheel, inches	For 5° clearance, B =	For 7° clearance, B =
2	.0937 = 3–32	.125 = 1–8
2¼	.099 = 3-32+	.141 = 9–64
2½	.110 = 7–64	.156 = 5–32
2¾	.125 = 1–8	.172 = 11–64
3	.132 = 1–8+	.187 = 3–16
3¼	.143 = 9–64	.203 = 13–64
3½	.154 = 5–32	.219 = 7–32
3¾	.165 = 5–32+	.234 = 15–64
4	.176 = 11–64	.250 = 1–4
4¼	.187 = 3–16	.265 = 17–64
4½	.198 = 13–64	.281 = 9–32
4¾	.209 = 13–64+	.297 = 19–64
5	.220 = 7–32	.312 = 5–16
5¼	.231 = 15–64	.328 = 21–64
5½	.242 = 15–64+	.344 = 11–32
5¾	.253 = 1–4	.359 = 23–64
6	.264 = 17–64	.375 = 3–8

TABLE 33.—DISK WHEEL CLEARANCE TABLE

Note.—If grinding wheel selected is too large, that is, if it scores the next tooth, a smaller wheel should be chosen and the centers readjusted so as to be right for this wheel.

SHARPENING PERIPHERAL TEETH OF A SIDE MILLING CUTTER

Figure 212 shows the "set-up" for grinding the peripheral teeth of a side-milling cutter with a cup wheel while Fig. 213 illustrates a similar operation as performed with a disk wheel. In both cases the tooth rest is mounted upon the swivel head on the table of the machine.

There is a centering gage for this machine which is used upon the table as shown on Fig. 217. This gage is the same height above the table as the work

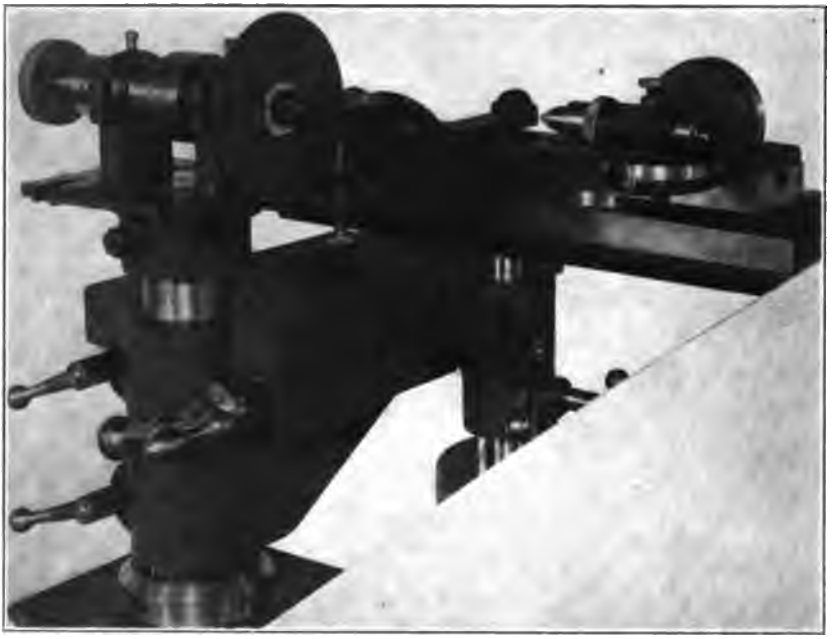


FIG. 211. CENTERING GAGE, CUTTER GRINDER.

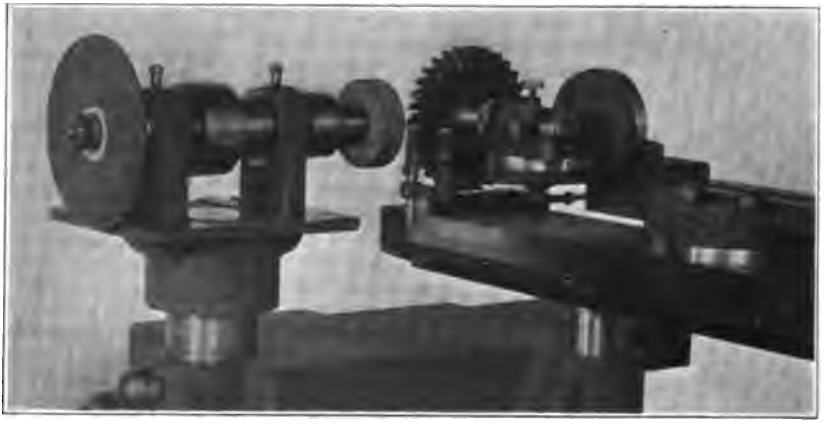


FIG. 212. SHARPENING PERIPHERAL TEETH OF A SIDE MILLING CUTTER WITH A CUP WHEEL.

centers. There are centering lugs on the rear side of the wheel head whose faces are on a line with the spindle so that when the table is adjusted to bring the gage to these lugs the work centers will be central with the spindle. The gage thus forms a means by which the cutter may be set central with the wheel spindle if desired, and the tooth rest set to the same height as either work centers or wheel spindle whatever their relative positions may be. A micrometer adjusment is provided for the table elevating device, and this micrometer dial in connection with the centering gage (from which initial settings are made) enables the work center and the tooth rest to be set in the proper vertical relation to the wheel spindle for obtaining any desired degree of clearance.

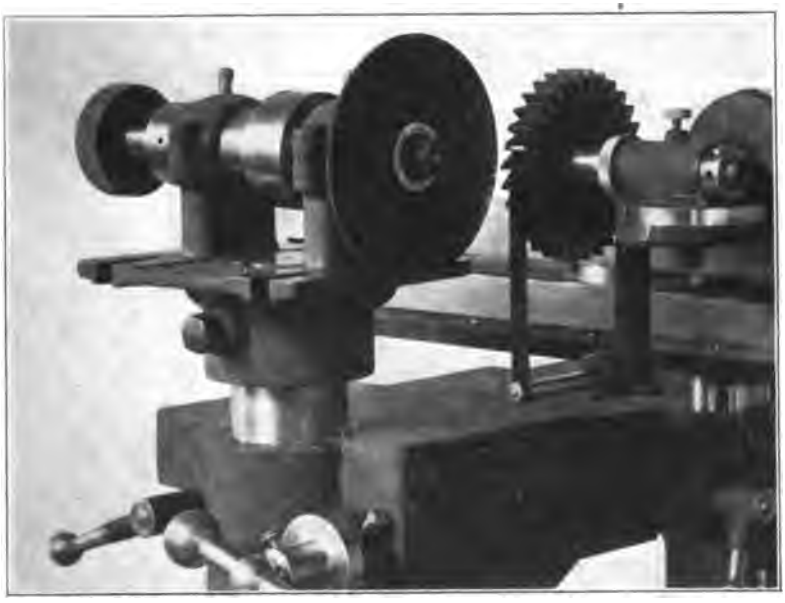


FIG. 213. SHARPENING PERIPHERAL. A SIDE MILLING CUTTER WITH A DISK WHEEL.

Referring again to Fig. 212, the top of the tooth rest when adjusted for this operation is set below the centering gage an amount required for the desired clearance as determined by Table 32. The knee is swung around on the column slightly (to 89 .1/2 degrees) to bring the "up" side of the wheel in contact with the cutter tooth. If the wheel strikes the tooth next to the one being ground the table should be elevated until the tooth clears the top of the wheel. The knee is easily set around to any desired angle as there is a large graduated collar and index pointer at the bottom of the knee bearing on the column.

USING THE DISK WHEEL

When using the disk wheel as in Fig. 213, the work center is set level with the wheel spindle by means of the centering gage, the micrometer dial set at zero and the table then lowered to bring the work center the required amount below the spindle center to give the desired clearance, as specified in Table 33. This amount of course varies with the diameter of wheel used. The tooth rest is of fixed type and its height is such that the face of the tooth being ground is the same height as the center of the cutter.

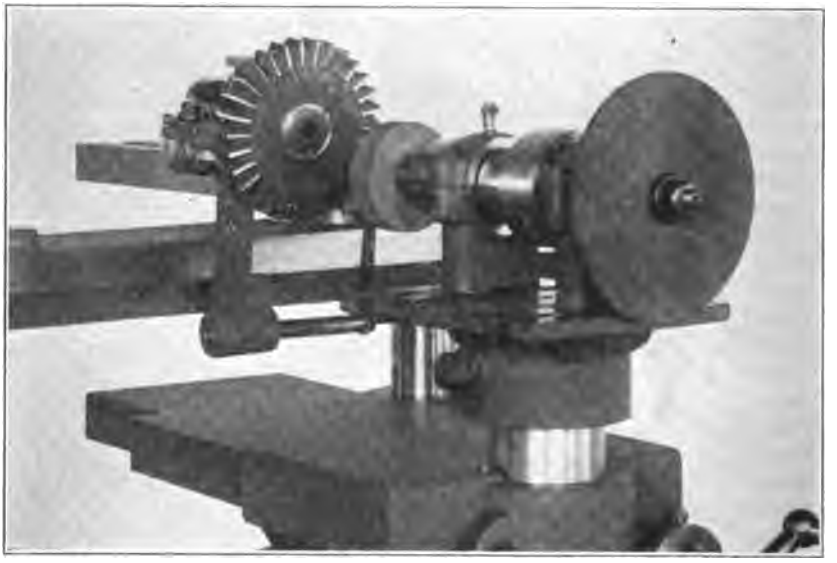


FIG. 214. SHARPENING SIDE TEETH OF SIDE MILLING CUTTER WITH A CUP WHEEL.

In all cases whether a cup or a disk wheel is used, the "up" side of the wheel should do the cutting as this reduces the tendency to draw the temper of the cutting edge, permits faster grinding and prevents the forming of a burr on the edge of the tooth which results when the grinding wheel runs in the opposite direction.

The cutter is held by hand against the tooth rest with sufficient pressure to prevent it from being lifted by the action of the wheel.

Of the two types of wheels shown in Figs. 212 and 213 the cup form is preferable for this operation as it gives a straight line clearance with a stronger cutting edge than is obtainable when grinding with a disk wheel sufficiently small to clear the adjacent teeth.

SHARPENING LEFT-SIDE TEETH OF A SIDE MILLING CUTTER

Figure 214 illustrates the method of sharpening the side teeth of a side milling cutter with a cup wheel, which, as already pointed out, gives a straight line clearance and a strong cutting edge. The cutter is held on the work spindle of the swiveling head and the head is depressed to an angle corresponding to the desired angle of clearance. The knee is set to 90 1/2 degrees so that the up side of the wheel will touch the work while the down side will clear. The tooth rest is fastened to the swiveling head. Its height is fixed so that the face of the tooth being ground is the same height as the center of the cutter.

The teeth on the right side of the cutter are ground in similar fashion, except that the cutter is reversed and the knee set to 89 1/2 degrees. The tooth rest is also reversed and the grinding is done on the side nearest the operator.

In both cases the table must, of course, be elevated until the tooth next the one being ground clears the top of the wheel.

SHARPENING A SPIRAL MILL

A disk wheel is seen in operation on the spiral mill in Fig. 215. Here the tooth rest is secured to the wheel head and its contact point is set to the height of the work centers by means of the centering gage after the table has been

FIG. 215. SHARPENING A SPIRAL MILL WITH A DISK WHEEL.

lowered to bring the work centers the necessary distance below the wheel spindle for the desired clearance. Table 33 is again used here as in the case of the operation shown by Fig. 213.

SHARPENING AN ANGULAR CUTTER

The right-hand angular cutter in Fig. 216 is held on the swiveling head spindle and the head swiveled to the required angle. The tooth rest is of fixed height and brings the face of the tooth being ground to the same height as the

center of the cutter. The table is lowered the required amount for clearance as given in Table 33, the centering gage being used as already described.

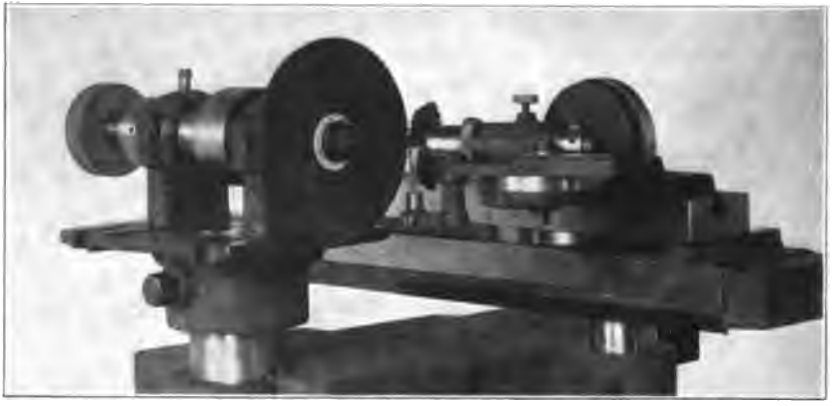


FIG. 216. SHARPENING A RIGHT HAND ANGULAR CUTTER.

SHARPENING A REAMER WITH THE CUP WHEEL

The hand reamer in Fig. 217 is supported between centers on the table and ground with a cup wheel, the knee being set 1/2 degree off the 90-degree mark

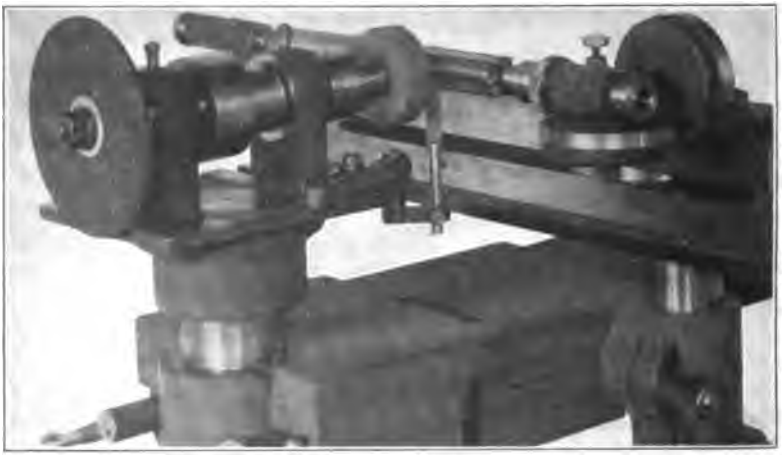


FIG. 217. GRINDING A REAMER WITH A CUP WHEEL.

to bring the up side of the wheel in contact with the work. The table is brought to proper height for grinding, the tooth rest adjusted to the gage, the micrometer dial set to zero and the table then elevated the amount required for clearance

as given in section 1 or 2, Table 31. The grinding operation may then be accomplished. As in the case of the cutter-sharpening process, if the wheel interferes with the reamer tooth next to the one being sharpened, the table must be raised until the tooth clears the top of the wheel, this must be done before setting the tooth rest and adjusting for clearance.

OTHER CUP WHEEL OPERATIONS—GRINDING A CIRCULAR FORMING TOOL

The circular forming tool in Fig. 218 is held on an arbor carried by the attachments furnished with the machine for grinding the faces of teeth on taps, hobs, formed cutters, etc. One end of the arbor fits the hole in the tail stock and the

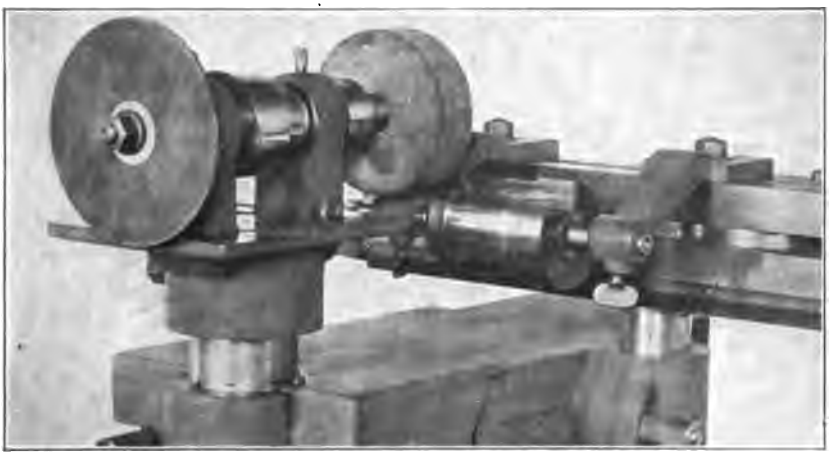


FIG. 218. GRINDING A CIRCULAR FORMING TOOL WITH A CUP WHEEL.

work can be clamped in any position, making it possible to grind the face of the tool, any desired amount past the center and parallel to or any angle to a given radius. The work must be revolved toward the wheel a slight amount at each grinding in order that the relation between the face of the tool and a given radius may always be preserved.

SHARPENING A LARGE SAW

A 24-in. metal saw is represented in Fig. 219 as ground with a cup wheel while held on a stud fastened to the table of the grinder at a point beyond the swiveling center of the table. The position of the tooth rest is clearly shown.

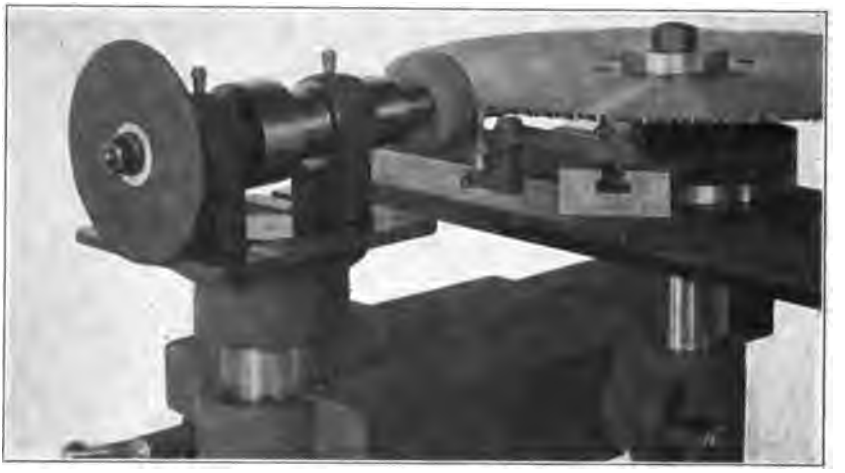


FIG. 219. A SAW-SHARPENING OPERATION WITH THE CUP WHEEL.

FIG. 220. SHARPENING A FORMED CUTTER.

USING A SAUCER WHEEL FOR SHARPENING A FORMED CUTTER

The cutter, Fig. 220, is mounted on an arbor between the special centers of the attachment shown. The table is first adjusted toward the column until the face of the saucer wheel is in line with the centers. The work is then put in place and the face of the cutter tooth brought against the face of the wheel. The tooth rest is then set to the heel of the tooth and the grinding proceeded with. The cutter should be revolved toward the wheel a slight amount at each grinding in order to keep the faces of the teeth radial.

GRINDING A CUTTER HUB FACE

The method of grinding the face of a cutter hub true with the bore is illustrated in Fig. 221. The cutter is held on a short split bushing on a taper arbor which is revolved between dead centers. A saucer-shaped wheel is used and the work is fed past the wheel by the cross-feed screw.

FIG. 221. GRINDING THE HUB OF A CUTTER TRUE WITH THE HOLE.

DISK AND CUP WHEELS IN SHARPENING LARGE INSERTED TOOTH CUTTERS

In Fig. 222 a cup wheel is shown grinding the side teeth of a 12-in. left-hand inserted tooth face mill. A special attachment for large mills is used and the cutter is held on a shank fitting the taper hole in the attachment. The tooth rest is fastened to the swiveling head and its height is fixed so that the face of the tooth being ground is the same height as the center of the cutter.

FIG. 222. SHARPENING THE SIDE-TEETH OF A LARGE TOOTH MILL.

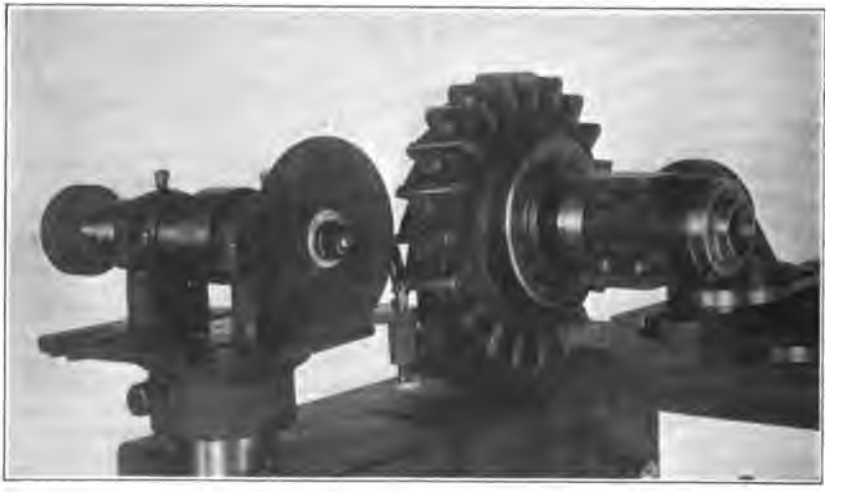


FIG. 223. SHARPENING THE PERIPHERAL TEETH OF A LARGE INSERTED TOOTH MILL.

In sharpening the peripheral teeth as shown in Fig. 223, the vertical swivel of the swivel head is set at zero to bring the cutter arbor parallel with the wheel spindle. As the teeth are set at an angle the operation is similar to the grinding of a spiral mill. The spiral tooth rest is used and the same method of obtaining the clearance followed as explained in connection with the spiral cutter operation in Fig. 215.

SPECIAL DEVICES FOR GRINDING AND GAGING CUTTERS

A number of special tools and methods are illustrated herewith as used in different shops for grinding and gaging cutters of various types.

Measuring Angular Cutters.—Some years ago H. E. Hext related in the *American Machinist*, his method of gaging angular milling cutters as follows:

We have a large amount of grinding to do on 90-degree milling cutters which have an angle of 45 degrees on either side of center line. The job for which the cutters were made requires that they be ground and gaged very accurately. The length of teeth must be equal on either side, bringing the points central with the sides of the cutter, as they run in pairs and are expected to reverse, or change places, on the cutter arbor.

The cutters in the several pairs which we keep on hand are of equal thickness, being 1/2 in. thick by about 2 3/4 in. diameter, when new. We experienced some difficulty in devising a gage with which we might prove that our cutters were correctly ground before sending them out to the machine room. We tried several methods of gaging with as many different degrees of success. The last method tried proved entirely satisfactory, and we have continued its use for this work.

THE FIRST COURSE OF PROCEDURE

When the first lot of cutters were ready for grinding we tried to do an accurate job in about the following manner: The sides of the cutters were first ground parallel and, as above stated, the cutters were finished to 1/2 in. thick. We next ground the teeth of one cutter as nearly right as possible by measuring with a scale; then, placing it on a cutter arbor in the milling machine, a cut was taken through a piece of 5/16 in. stock clamped in the vise. We then reversed the cutter on the arbor and milled back through the cut, noticing which side of the cutter cut away stock. A few "cut and try" operations were then performed, which consisted of grinding the high side and milling new notches until finally the cutter would reverse and pass through the cut, nicely cutting away a wash of copper solution. Leaving the cutter in its position on the arbor, a notch was milled in a piece of 5/16 in. stock to be used as a gage, *A*, Fig. 224, with which to test the grinding of the other cutters. Now having a gage for the job we proceeded as follows:

Setting the head on the grinder at 45 degrees and mounting a cutter on the holder, one side was ground until all the teeth on that side were brought to a sharp edge. Then reversing the cutter on the holder and swinging the head around 90 degrees for the other side, we ground off light cuts, testing with the gage after each cut around to ascertain when all the cutting edges on this side were of the same length as those on the first side ground. Each tooth of a

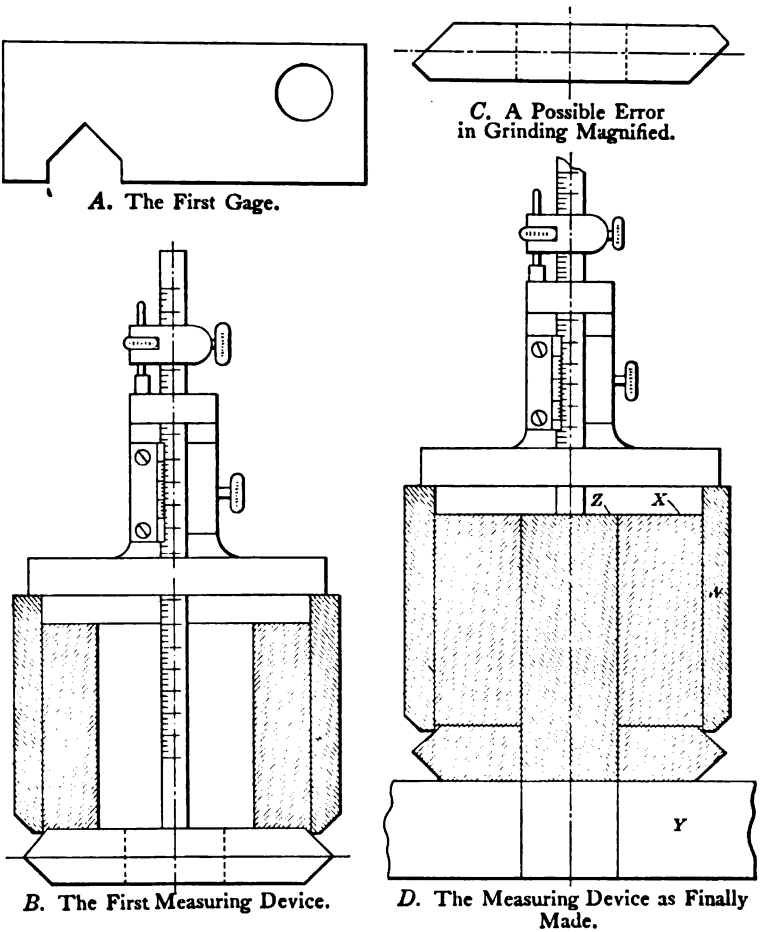


FIG. 224. DEVICES FOR GAGING CUTTERS.

cutter in this condition would exactly fit the gage. But we found that some of the teeth were ground down to size before others, and that when the high ones were ground to fit the gage fairly well, the low ones were too low, thus leaving us in the dark as to whether both sides of the cutter would cut alike or not. Moreover, cutters gaged in this way were frequently returned from the machine

room with complaints that they did not mill a smooth finish, or that the grooves milled were not of equal depth, or perhaps some other defect would be mentioned, any of which would render the cutters unfit for use. It did not require a great deal of experimenting to convince us that this gage was not just what we needed, nor was it the fault of the gage. It was assumed that the cutter grinder we were using would grind both sides of the cutter concentric, and also that the cutter would rotate (while being ground) in a plane at right angles to the axis of the holder. We found, however, that we could not depend upon a high degree of accuracy in this respect, and we also found that the teeth were ground a trifle irregular, some of them being noticeably higher on one or both sides than others, notwithstanding the fact that each side of the cutter was ground on a fixed center.

ANOTHER DRAWBACK TO THE GAGE

Another serious objection to this gage was the difficulty of grinding the diameters of the cutters in each pair alike. To do this one cutter was first ground in the above described manner and its diameter measured with a micrometer. Then we ground the second cutter to the same diameter by grinding off the points of the teeth parallel with the axis. Now, to reduce the teeth to gage size we could not grind off just the amount of stock that should be ground from one side and then reverse for the other side and finish, because our gage gave us no indication where the stopping-point should be on the side first ground. We might grind off too much from the first side and not discover our mistake until we found our diameter too small, which would be the case when the teeth were finished by grinding the other side until they fitted in the gage. This would make it necessary to regrind the first cutter to reduce its diameter to that of the second cutter ground. For this reason it was necessary to take light cuts from both sides of the cutter, reversing the cutter and swinging the head around after each cut in order to keep on the safe side and finally bring the points of the teeth up exactly on the center line of the cutter, when the gage would fit. This would be a tedious operation and occupy too much time, so we began casting about for an expedient whereby a number of cutters might be ground to a given diameter without the annoyance of resetting.

THE MEASURING DEVICE

We decided that we should have a measuring device, and *B* is a sketch of the rig we planned and made with which to measure the cutters. It consisted of two rings ground and lapped to fit one within the other, as shown, the outside ring being hardened and the ends ground square with the axis. The inside diameter of the hardened ring was of a size which would allow it to pass only a short distance over the sides of the teeth, as shown, thus allowing for grinding,

as the ring would rest a little nearer the points of the teeth after each grinding, and if it had been made much larger than was necessary for use on new cutters the diameters of the cutters might be reduced to the inside diameter of the ring before the cutters were used up, when new rings would have had to be made. The object in using the inside ring is to keep the large ring square with the sides of the cutter when measuring. A micrometer or vernier depth gage may be used to measure the distance down to the side of the cutter, or to the top of the inside ring. We use a Brown & Sharpe vernier gage, at *B* and *D*. In measuring by this method our practice is first to grind one side of a cutter and apply the rings and depth gage, as shown in *B*, measuring to a point on the cutter near the hole and noting the reading on the vernier. We then take a light cut from the corresponding side of the other cutter, remove the cutter and measure as before. If the gage shows that there is more stock to remove, we replace the cutter in the same position and take another light cut around, repeating this operation until the side of this cutter or the corresponding sides of as many as we may have to grind at one grinding, are reduced so that the depth gage registers the reading first noted. If, however, there are several pairs of different diameters to grind, it is best to grind each pair alike, setting down the several vernier readings. We then reset the head for the other side and grind the side of each cutter until the vernier registers the same as on the opposite side. By this means of measuring we have to swing the grinder head around only once. The time occupied in grinding was greatly reduced and the task of grinding became pleasant and interesting instead of irksome. Then, too, the cutters sent to the machine room remained in service until dulled.

AN IMPORTANT MODIFICATION

We were satisfied with this measuring rig until we discovered that while the cutters thus gaged had done the work well, it did not afford absolute proof that the cutters were properly ground. Suppose, for instance, a cutter should be ground as shown at *C*, which shows an exaggerated view of how it might be ground by reason of a loosely fitting arbor or holder, which would allow the two sides to be ground eccentric to each other in case (as with us) the cutter had to be reversed in order to grind both sides. Now the depth gage might register the same for either side, still it would prove that the cutter would do the work properly or that two cutters ground and gaged in this way would cut alike. The reason is that the outer ring, when placed on the cutter, finds the center on which that side was ground instead of the center on which the cutter rotates when milling; thus, instead of gaging from the high teeth (or possibly only one tooth), which actually do the work, it shifts over, allowing the ring to rest nearer the points of the teeth, making the distance from the top of the outside ring to the side of cutter less than it would be if the rings were held concentric with the hole in the cutter.

To overcome this inaccuracy we made over and added to the measuring rig, so as to look like *D*. Using the same outside ring *W*, we made another inside ring X, the hole in which was lapped to the size of the hole in the cutters. We then made a base plate *Y*, in which was fitted a standard *Z*, square with the plate. The cutter to be measured is slipped over the standard, followed by the rings, and the depth gage is applied as shown at *D*, measuring to the top of the inner ring (instead of down to the cutter as in *B*), which is necessary because the inside ring fills the space between the outside ring and the standard. By thus holding the rings to the center on which the cutter rotates when working, the outside ring gages from the highest teeth. These teeth perform the work and therefore form the proper gage point.

ACCURATE RESULTS OBTAINED

A pair of cutters measured in this way, if mounted in the milling machine on a true and properly fitting arbor, will cut grooves exactly alike.

This method of gaging is not confined to cutters of this particular shape and angle, but may be used for gaging any ordinary angle cutter when it is required to have two or more cut alike or to have one cutter ground alike on both sides. It might be necessary on account of too great variation in diameter of the cutters, to have two sets of rings, and if the holes in the cutters were of different size, to make several standards for the base plate, or one standard for the smallest hole and bushings for the larger sizes.

GRINDING MILLING CUTTERS IN THE LATHE[1]

While extensive grinding operations upon the lathe cannot be generally recommended, some are necessary and others may effect saving far outweighing any loss due to depreciation of the machine used. Many shops using milling cutters, end mills, etc., are not equipped with a cutter grinder, making it necessary to send out the cutters to be ground; besides the fancy prices usually charged for this work, it often causes undesirable delay, especially when a "hurry job" is to be done.

While presenting nothing new in principle the following description may disclose some novel features in the appliances especially designed and used to grind the most used milling cutters of the shop upon the ordinary lathe. Besides the special tools, described in order, a small center grinder taking a 5-in wheel at 4000 r. p. m., such as is usually found in the equipment of most shops is essential.

GRINDING SMALL MILLS

Straight-fluted right- and left-hand mills, with straight or taper shanks, ranging in size from 1/4 to 1/2 in. are put on centers and the small angle bracket shown in Fig. 225 screwed to the drive plate of the lathe. An adjustable spring-

[1] Arthur F. Kunze.

copper stop is provided on the end of this bracket, supporting the edge being ground. Clearance is given the cutter by turning the lathe spindle slightly forward or backward as the case may require. These small mills, usually plain on the ends, require no grinding there.

For spiral mills of the above description the device shown at *X*, Fig. 226, is used. Shell *C* fits the taper in the lathe spindle. *B* is a guide socket which is an easy sliding fit in shell *C*. The screw *A* extending through *B* acts as a draw rod and holds a special collet required for grinding these mills, as well as screw-shank mills.

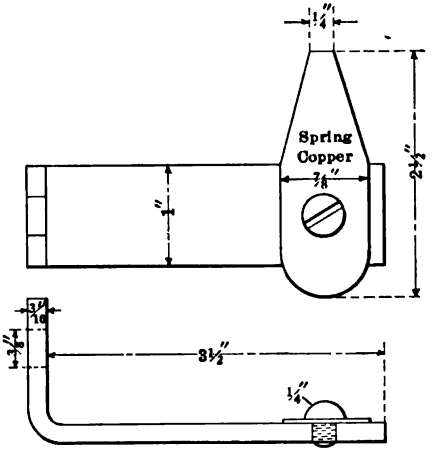


FIG. 225. BRACKET AND TOOTH STOP FOR CUTTER GRINDING ON THE LATHE.

AN ADJUSTABLE REST

An adjustable rest required for a number of these grinding operations is shown at *Y*. It must be borne in mind that this device had to be made at a minimum of cost, and while not above criticism was found to work very nicely. It has a vertical post with screw and nut at the bottom, for vertical adjustment. This allows for giving the mill the proper clearance. After adjustment is made the post is set securely by a set screw at the side. Cross adjustment for grinding work from o to 8 in. in diameter is provided through the cross bar *A*, as shown at *Y*.

For grinding screw-shank, T-slot and other similar cutters, the device shown at *X* is put into the lathe and the attachment, *Y*, clamped in position. The mill is held in position in *B* by the draw-in rod, the stop adjusted to give the proper clearance and the guide socket *B* moved back and forth with the spiral edge to be ground following over the stop.

T-slot mills are held in this device, but the lathe carriage with the grinder is moved while the mill is at rest with the edge being ground resting upon the

stop. Small straight- and taper-shank spiral mills are ground like screw shank except that special collets must be used, as already mentioned.

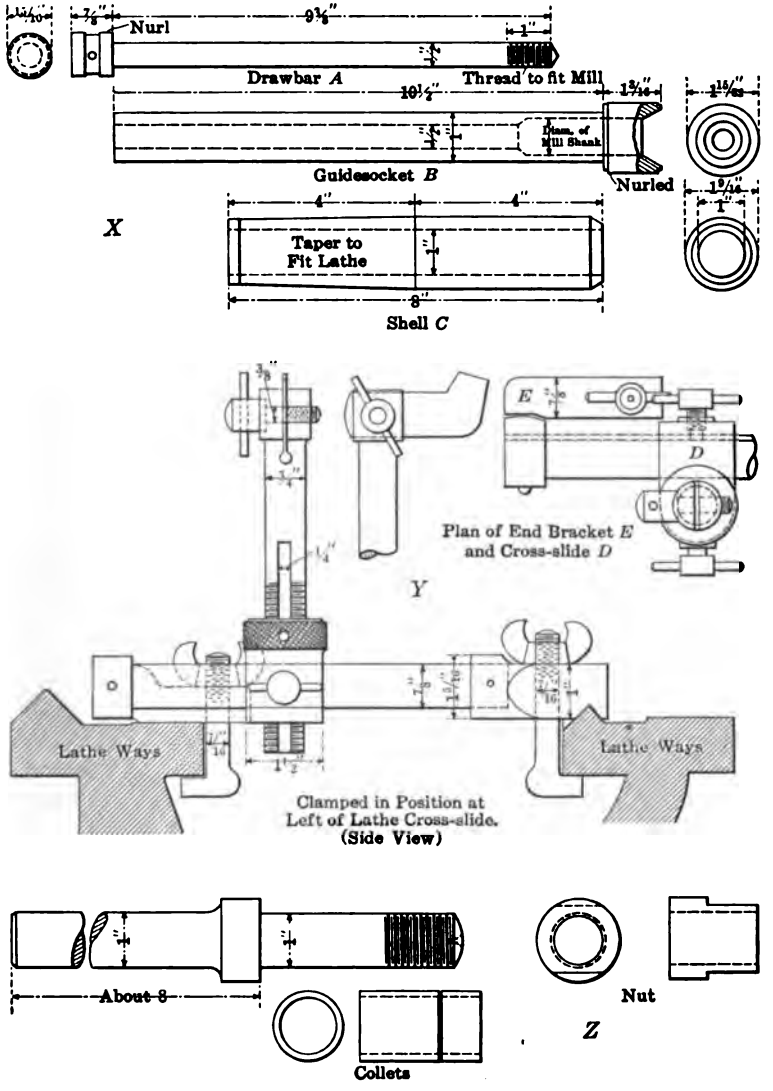


FIG. 226. GRINDING ATTACHMENT FOR LATHE.

HANDLING FACE MILLS

Face mills up to 6 or 8 in. in length, and inserted-blade mills with straight or spiral flutes are put upon a mandrel which is held on the centers. The cutter

must be an easy sliding fit as the grinder in this case is stationary while the mill is moved with the left hand, giving it a gentle forward pressure, the spiral flute thus moving over the stop, directly in front of which the emery wheel revolves.

Side mills and saws, by reason of the fact that they are too thin to have sufficient bearing surface to slide upon a mandrel, are screwed upon a shoulder mandrel shown at *Z*. This mandrel is carried upon the lathe centers, the stops adjusted under the tooth to be ground and the carriage of the lathe moved back and forth by the hand wheel. In this case again the tool to be ground is stationary while the lathe carriage moves. The flutes or teeth in this case must be straight as they usually are in narrow cutters and saws.

ANGLE MILLS AND REAMERS

Angle mills of 40 and 60 degrees were also ground as well as side edges of side mills; this is done by setting the cross slide to the proper angle and using the cross-slide screw. This method, or rather the grinding of this class of work, was found cumbersome and is not recommended here. Reamers, both straight and taper, may also be ground by using the device at *Y*.

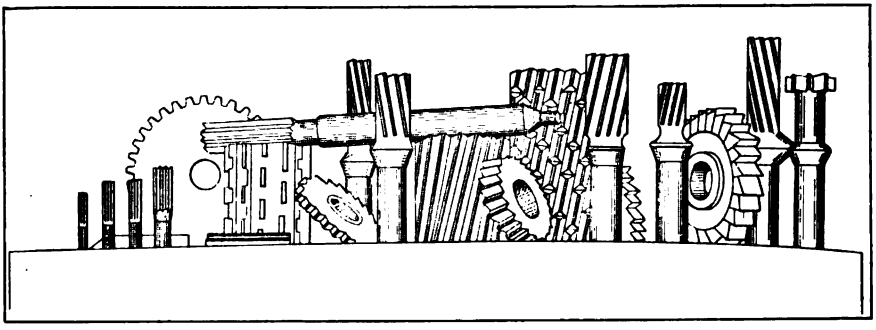


FIG. 227. SPECIAL DEVICES FOR GRINDING AND GAGING CUTTER.

The line cut, Fig. 227, shows a number of cutters ground with these appliances which have been in use for some time and have effected a saving of from 25 to 50 per cent., besides affording the convenience of grinding up a cutter at short notice right in the shop.

It is freely admitted that while all cutters should be ground on a grinder, that it would not be advisable to attempt to grind odd-shaped cutters; in the absence of a grinder, however, this method of grinding the ordinary cutters of the shop will be found convenient and inexpensive.

GRINDING ROTARY PLANER CUTTERS

Figure 228 shows a grinding rig for cutter heads for rotary planers, making use of a Hisey-Wolf portable grinder. There are three of these rotary planers

in use in a Canadian shop with 60 tools in each. It formerly took from 3 1/2 to 4 hours weekly to change the tools alone for grinding. The tools are now ground in place in 30 minutes and they are ground perfectly, which was not the case formerly. They are now generally run for 3 months without changing tools.

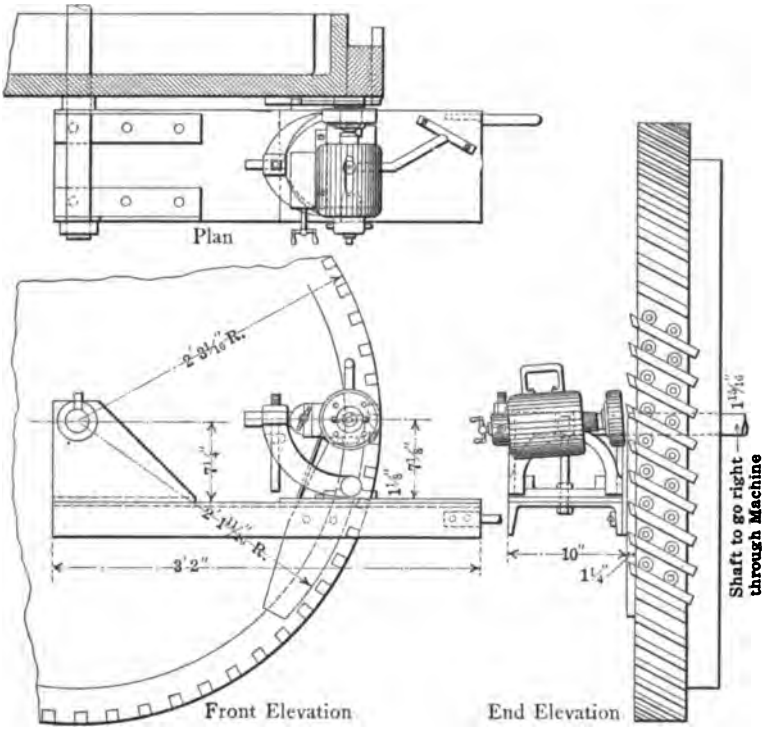


FIG. 228. GRINDING RIG FOR ROTARY PLANER CUTTERS.

FIXTURE FOR GRINDING FORMED CUTTERS

Some years ago E. Lawrenz came across a pair of milling cutters about 16 in. in diameter and about 2 1/2-in. face. The blades were inserted and were, strictly speaking, formed cutters because, as is shown in section at *X*, Fig. 229, they were adapted to cut fillets of 1/8- and 3/8-in. radius, or thereabout, and a variation of a few thousandths, even 1/64 in. in their radii, would make no difference.

He was told that these cutters had been in use without sharpening for about 2 years.

The grinder in the shop was a good machine insofar as it was substantially built; one of oldtime design and execution. The spindle bearing, or headstock, was bolted on top of the column, which enabled the bearing to be raised enough

to permit of greater range between wheel and platen. The next step was to design a fixture to so mount the cutters thereon that the centers of curvature of the cutter corners would coincide with the center line of the fixture proper.

Figure 229 shows the solution of this problem. *W* is the main frame supporting the apron *B* by means of the two trunnions *C*. On the right-hand side is the segment *D*, fastened to *C* and having two stopping points *L* and *M*; *i.e.*, *L* is a pin which fits and locks segment *D* at either extremity. Through the trunnion *C*, on the left side, a pin, or lever *E* is held in place by set-screw *S*. Between the bearing of *W* and the rod *E* is a washer *F*, the purpose of which is to hold the bearing *S* firmly between itself and the nearest boss of the apron *B*, in which the trunnions are firmly held, thus giving the fixture rigidity, which otherwise could not be attained except by an abundance of cast iron.

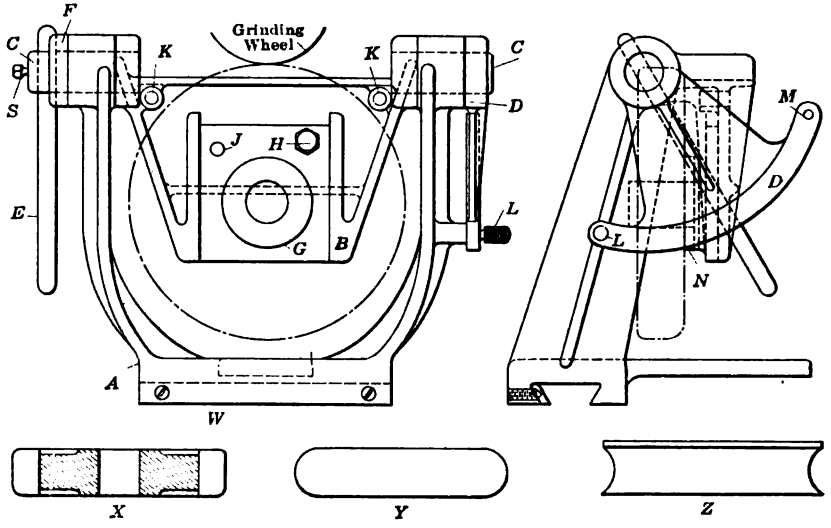


FIG. 229. FIXTURE FOR GRINDING FORMED CUTTERS.

Upon the apron *B* is fitted the slide *G*, carrying a suitable arbor fitting into the cutters. In apron *B* and the slide *G* are bolt holes such that, when either *H* or *J* is brought into register with its mating hole, the center of curvature of the cutter will be brought into the vertical plane passing through the center of the fixture. Upon the arbor of *G* is slipped the washer *N*, which is of such thickness as to bring the center of curvature of the cutter corners into a plane passing through the center of the fixture parallel to the plane of *G*. Of course, two washers must be used and the difference in their thickness must be equal to the difference between the radii of the two curves on the cutter.

Now, by placing the cutters upon this fixture, the cutters may be sharpened in the position shown in the sketch, grinding tooth after tooth, these being en-

gaged by suitable fingers placed into either of the holes *K*, as may be needed. Having ground one face, the curves may be sharpened, then one of the sides; after this *G* must be moved, the correct collar *N* selected and the last side and curve ground. The circles are ground while apron *B* is swung from the position shown, to a horizontal position, by means of rod *E*, the pin *L* being removed. To grind these two cutters required one-half hour, and the cost of the whole fixture did not exceed $50, the patterns being the most expensive part. How useful this tool was can be appreciated from the fact that the cutters were sharpened every week.

Looking this apparatus over, we can see that it not only easily can guide a cutter of form shown at *X*, but that it equally well can be made to grind shapes shown at *Y* and *Z*. It also may grind any external angle we please, simply by making the apex of such angle coincide with the axis of the fixture. The shape shown at *Z* may approach a half circle, the only limitation being the thickness of the wheel.

LARGE RADIUS MILLING CUTTER AND GRINDING FIXTURE

The engraving, Fig. 230, shows a 3-in. radius milling cutter 12 in. in diameter which was designed by C. E. Chamberlain some time ago to do a job on an

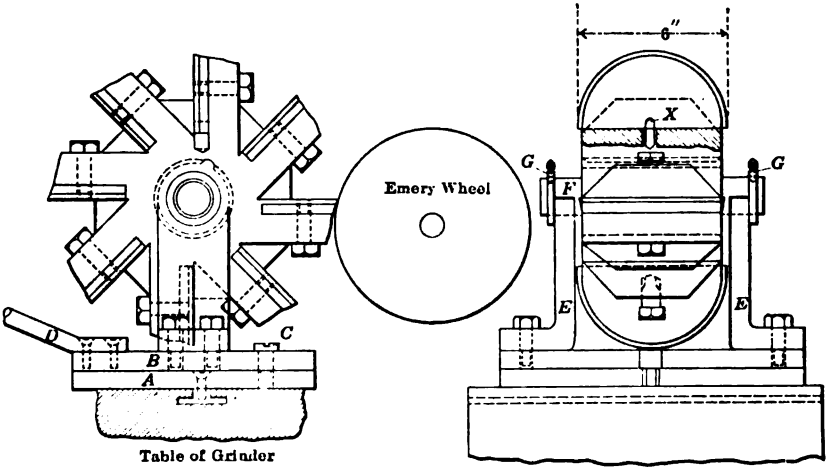


FIG. 230. LARGE RADIUS MILLING CUTTER AND ITS GRINDING FIXTURE.

Ingersoll milling machine; a fixture for grinding it is also shown. While the milling cutter may not be new, the fixture for grinding it will be of interest.

The milling cutter consists of a soft-steel center or body bored to fit the arbor of the milling machine and turned 1/4 in. smaller in diameter than the blades, which are held in place by 1/2-in. hexagon head tap bolts and a slot in the center which is a fit over the pin *X*. The grinding fixture consists of a plate *A* fastened

to the table of the grinding machine and plate *B* held in position by the pin *C* which is the center of the radius around which the cutter is swung by the handle *D*. The cutter is held in position on the half bearings *E E* and arbor *F* which is a driving fit. The collars *G* can be adjusted to bring the center of the cutter in line with the pin *C*.

The grinding can best be accomplished on a machine where the emery wheel can be raised or lowered so as to obtain the correct amount of clearance.

ANOTHER GRINDING FIXTURE FOR FORMED CUTTERS[1]

A certain job requires a gang of three milling cutters as shown in Fig. 231, the two outside ones having a circular face, the center one an ordinary straight face. Primarily the outside cutters were made to sharpen by grinding on the

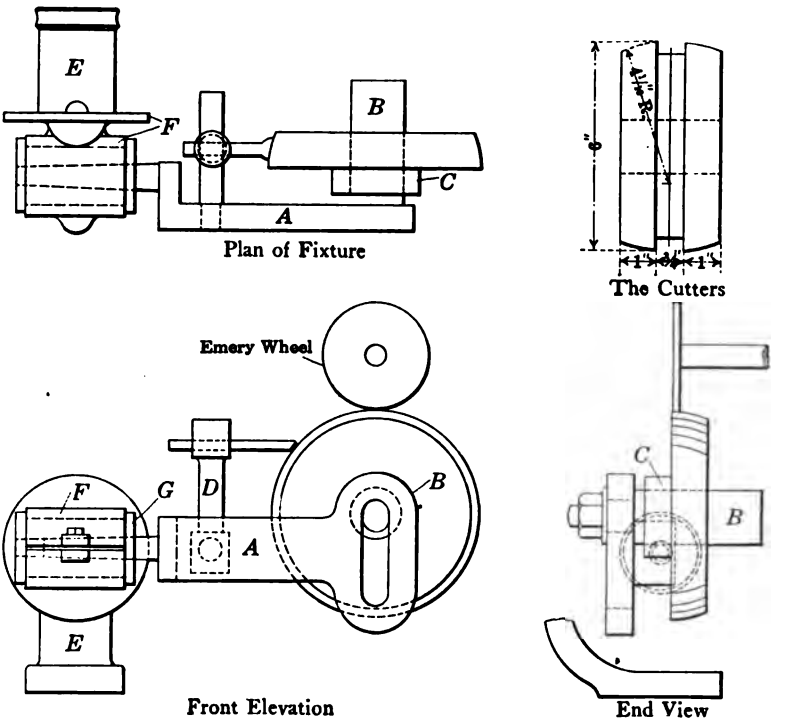


FIG. 231. ANOTHER GRINDING FIXTURE FOR FORMED CUTTERS.

face of the teeth, but owing to the manner in which they became worn this necessitated too much grinding. The cutters as now used are ground upon the edge in the same way as ordinary cutters but special means had to be adopted so as to obtain the proper curve quickly, the fixture shown being made for this

[1] W. O. Harrup.

purpose. It will be noticed that the center of the tooth-form circle does not coincide with the center of the cutters but lies 3/8 in. from the inner faces and is for a larger radius.

The cutter grinder was already fitted with a universal head *E F G*, having a taper hole into which the mandrels are placed. The bracket *E* is fixed to the table of the machine and carries the graduated portion *F* which can be adjusted by worm and worm wheel to obtain the requisite amount of clearance. Working in *F* is the barrel *G* into which the stem of the fixture is placed and by means of which the fixture and the cutter are given a revolving motion.

The fixture proper consists of a forging *A* having a taper stem at one end and a slot at right angles to its axis at the other. As will be seen from the plan, this slotted portion is offset from the center of the stem and is fitted with a mandrel *B* to carry one cutter. The mandrel can be adjusted in the slot so as to bring the center of the stem and the tooth circle in line and the cutter can be adjusted sideways upon the mandrel by means of collar *C*. An adjustable tooth rest is mounted upon the arm of the fixture, the whole arrangement revolving together.

The views show the emery wheel in position ready to grind a tooth but for the sake of clearness the whole of bracket *E* is not shown in the end view. This fixture can be used for any circular-shaped cutter within its range and is not only applicable to this one job. It might be asked why both cutters are not ground up at the one time, and this could easily be done, but we would have needed a stronger universal head and also the arm of the fixture would have to have a greater offset

A gage is used during grinding, the three cutters being slipped on a mandrel and tested with it to see that an equal amount is taken off both the outside ones. Of course, the cutter and fixture are only given a rocking motion and do not revolve in a complete circle.

METHODS OF GRINDING GEAR CUTTERS

A correspondent from Milwaukee states that when he receives a gear cutter from the makers, the first thing he does is to put it on a mandrel and between centers and use a test indicator to test every tooth on the cutting edge, as shown in Fig. 232.

Almost invariably the teeth show a variation of 0.002 to 0.005 in. He then marks all the high teeth. Next he mounts the cutter on an arbor which fits in the spindle of the head of milling machine, using a disk wheel whose face has been set in the center of the spindle or cutter as in Fig. 234. The gage finger is then brought up against the back of the tooth at *A*, Fig. 233, then all high teeth are ground off on the cutting edge or face at *B* and the process continued until all the teeth indicate the same height. He uses the finger for feeding the tooth up against the wheel, thereby maintaining all cutting-edge lines through the center of the cutter.

When all the teeth show the same height, the arbor is tapped out with the cutter mounted, put between centers as before and an indicator used to prove that all teeth show the same height.

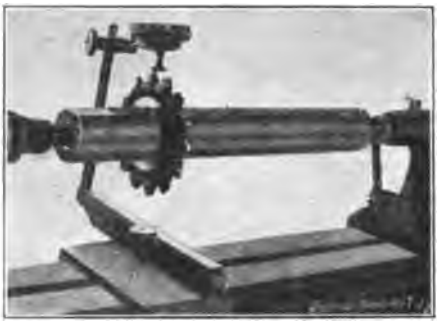


FIG. 232. TESTING A NEW CUTTER.

The cutter is now reversed on the arbor and the backs of all the teeth ground to correspond with the true cutting edge or surface, by bringing the finger against the surface of the tooth. The cutter is now put in the tool-room rack

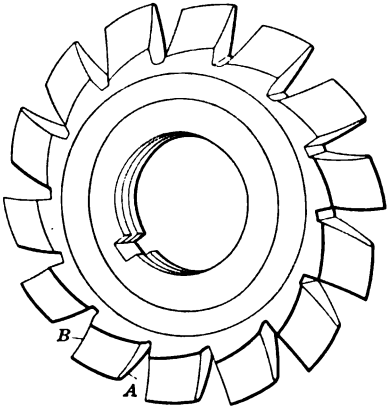


FIG. 233. CUTTER TO BE TRUED UP.

ready for use. In resharpening this cutter, it can readily be seen that it requires no further testing for the next four or five sharpenings; just bring the finger up against the back of the teeth and grind in the usual way.

GRINDING A GEAR CUTTER BY HAND

To grind a gear cutter by hand, that is to say without the necessary attachment, so that the tops of the teeth will continue equidistant from the center of the

cutter is no easy matter, and it is necessary to have some quick and easy means of measuring to obtain good results. This can be done by measuring the distance from the face of the hole to the tops of the teeth by a micrometer. This operation needs some care because the anvil of the micrometer makes only two points of contact with the face of the hole and to keep moving it around the hole in the

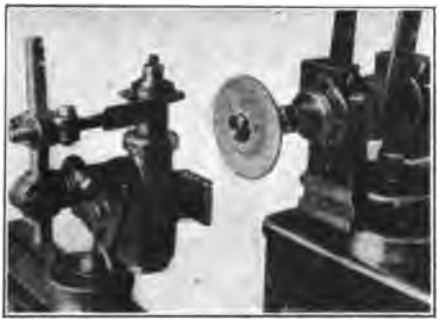


FIG. 234. GRINDING THE CUTTER.

process of measuring each tooth, is detrimental to the instrument. To obviate this an attachment was made as in Fig. 235, to suit the hole in the cutter (which was 1 in. diameter in this case) and the anvil of the micrometer. A piece of 1 in. cold rolled steel about 1/2 in. long, was sawed through the center of the section, thus making two semi-circular pieces; one of these was faced true across the diameter, also parallel with the horizontal line, taking care that the thickness of the piece and the thickness of the anvil end of the micrometer together measured not more than 1 in. Using this face as a base, a hole was drilled about 0.002 in. larger than the diameter of the anvil of the 2-in. micrometer.

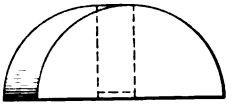


FIG. 235. ATTACHMENT FOR MICROMETER FOR MEASURING GEAR CUTTER TEETH WHEN GRINDING.

Obtaining a piece of drill-rod which would be a driving fit in this hole, one end was faced true and a piece cut off about 1/32 in. shorter than the length of the hole; this was pressed in, faced-end foremost, to within 1/32 in. of the base, thus leaving a recess. The other end was, of course, rounded off level with the curved surface. Slipped over the micrometer anvil the piece now forms a solid and effective measuring base.

ANOTHER GEAR CUTTER-GRINDING KINK

Another simple device for this same purpose is shown in Fig. 236. In this sketch *A* is a round plate somewhat larger than the cutters to be ground and with a notch cut in it so that when the cutter is mounted on stud *B* it allows the

emery wheel to grind the face of the cutter in the usual way. *C* is a clamp with a point as shown, held on the plate by cap screw *D*. Now all that is necessary to grind a cutter correctly is to mount it on stud *B* and after grinding one tooth in the usual way adjust the clamp *C* until it will just allow the ground tooth to pass when the cutter is revolved on the stud, and then continue to grind the teeth until they all pass by in the same way. We then have a true cutter.

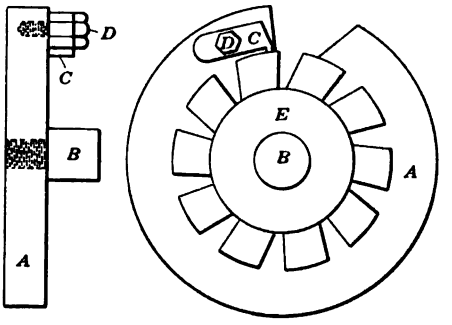


FIG. 236. GEAR CUTTER, GRINDING KINK.

GRINDING SPROCKET CUTTERS[1]

Having a large number of sprocket cutters to keep sharp and no means of grinding them quickly and accurately, the special attachment, Fig. 237, was designed to meet the needs of the work.

When a large cutter is sharpened on an ordinary grinder it is necessary to set the cutter three times, once to grind across the point of the teeth, and once to sharpen each edge which cannot be reached by the first setting.

The drawing shows a scheme which will allow a cutter to be ground radially and the whole cutting edge sharpened at one setting. It also provides a means for indexing the cutter accurately and thus keeps the sprocket cutter teeth the same length. Hence all the teeth cut equally and this lessens the chance of breaking a tooth.

In laying out the fixture care was taken to pick out the largest cutter in stock and make the yoke *Y* wide enough to accommodate it. This also determined the length of the base *B*, which was made to slide in the slotted grinder table. The taper stud *T* fitted into the yoke and was provided with a square shoulder *X* to accurately locate the index plate *I*. The split bushing *A* was made to fit the hole in the cutters, and by tightening the nut the cutter can be locked to the stud. The stop *S*, shown in the top view, worked into the notches in the index plate *I*, making an easy means of indexing the work. An index plate had to be made for each cutter having a different number of teeth. When cutters of an odd number of teeth are ground it is necessary to shift the stop *S* radially on the

[1] C. C. Myers.

circular projection E until the correct position conforming to the teeth in the cutter is reached. Then it is clamped in position.

At the left end of the fixture is shown a worm wheel which provides an easy method of rotating the cutter from position 1 to position 2 and 3 and grinding the whole cutting edge.

The method of operating is to attach the cutter to the stud T and line up the edge of the tooth with the index plate. This is easily done by having

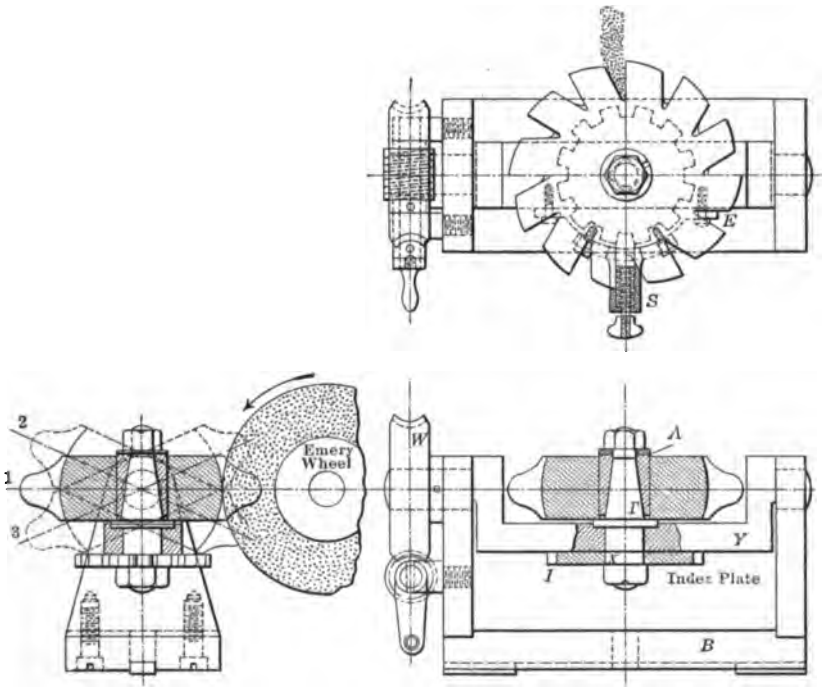


FIG. 237. SPROCKET CUTTER GRINDING ATTACHMENT.

radial lines marked on the index plate. The grinder table is fed forward to the right position, the tooth rotated, the table fed back, the sprocket indexed, and the operations repeated. The time of grinding is reduced to one-third the time originally consumed, and a much more accurate job obtained.

The same fixture may be used for grinding all other forms of gear cutters, and by providing the requisite bushings it is made availabe for a wide variety of work.

FIXTURE FOR GRINDING CIRCULAR SCREW-MACHINE TOOLS

The illustration in Fig. 238 shows a fixture designed by T. H. Sylvan for holding circular screw-machine tools while grinding the cutting face. A cast-iron base is provided with slots for bolting to the grinder table and a tongue for fitting the slot. Into the web *B* are tapped four square-head set-screws *C*, provided with check nuts *D*. These are for setting the grinding wheel to grind different distances below center, and are adjusted and locked in place, and the table is raised until the grinding wheel just rests on one of these screws.

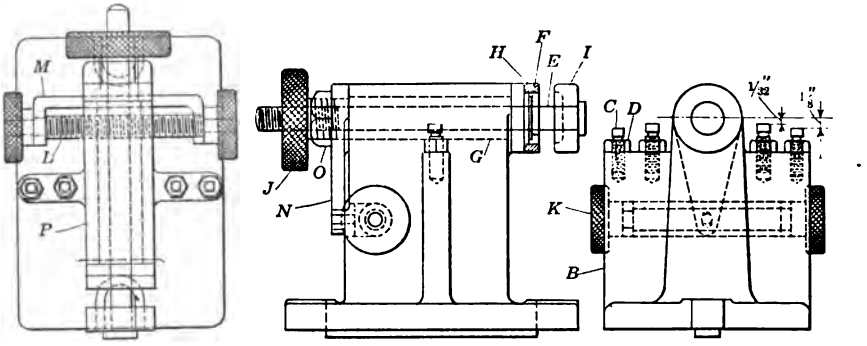


FIG. 238. FIXTURE FOR GRINDING CIRCULAR SCREW-MACHINE TOOLS.

The cutter to be ground is mounted on the spindle *E*, if it is for the No. 00 Brown & Sharpe machine, and on one of the steps *F*, on the shaft *G*, if for a larger size machine.

Collars *H* of various thicknesses are used, depending on what step the cutter is mounted.

The cutter is securely clamped in place between the collar *H* and washer *I* by tightening the nut *J* on the end of *E*.

The cutter is revolved by turning the nut *K* on the screw *L*, which is tapped through the web *P* of the base. Turning the nut moves the yoke *M* back and forth. The arm *N* is connected to the yoke and clamped against the end of the shaft *G* by means of the nut *O*.

When the grinding is finished, the cutter is removed from the fixture by loosening the nut *J* and removing the spindle.

GAGE FOR SHARPENING CIRCULAR CUTTERS

Figure 239 shows a German gage used in grinding the cutting faces of circular tools of varying diameters, so that the proper cutting angle of the tool may be retained. It provides that the cutting edge of the tool shall be constantly at 10 degrees from the radial, instead of being ground to the "1/4-in. rule" used generally.

There is a beam *a* with a movable jaw *b* and a fixed one *c*. The fixed jaw at the upper end of the beam has a hub *d* screwed or riveted in it, that is adapted to receive bushings *e*, that will fit the center holes of the circular tools. On to the fixed jaw *c* is riveted a piece of sheet metal *f*, one edge of which forms an angle of 10 degrees with the fixed jaw and points radially to the center of pin *d*.

In using the tool the circular-shape tool *g* is set on the hub *d* with its proper bushing, the movable jaw *b* is set to the intersection of the radial edge of piece *f* with the circumference of the circular tool, as shown, and by simply sighting across the edge of jaw *b* it will be seen whether the tool is ground correctly or not.

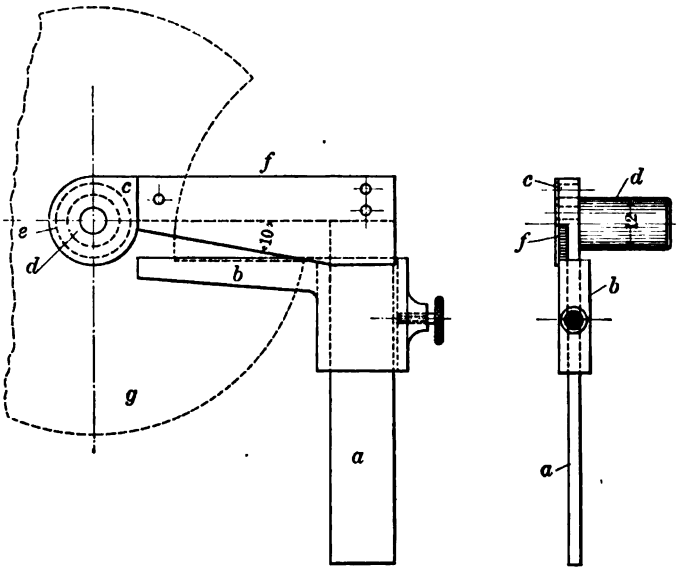


FIG. 239. GAGE FOR GRINDING CIRCULAR CUTTERS.

FIXTURE FOR GRINDING BORING BAR CUTTERS

It is often a difficult task to grind boring bar and counterbore cutters and have the lips or cutting surfaces come anywhere near correct. Usually the variation of the lips on large cutters will be so great if ground by hand as to strain the boring bar. To overcome the difficulty a fixture was designed as in Fig. 240, which will enable both lips of the cutter to be ground at one setting. When the first lip is ground, loosen bolt at the pivot, then turn section *A* half way around and the other lip will be in position.

The cutter *a* is set for grinding, *b* is the taper slide with a detachable stop *c*. Stop *c* should be made of tool steel hardened and in three or four sizes, to correspond with the width of cutters. It is essential that the center of the cutting

edge should be in line with the pivot, as illustrated at center line *d*, which can easily be adjusted with the taper slide.

This fixture can be adapted to almost any grinder. The best results are obtained by the use of a cup wheel.

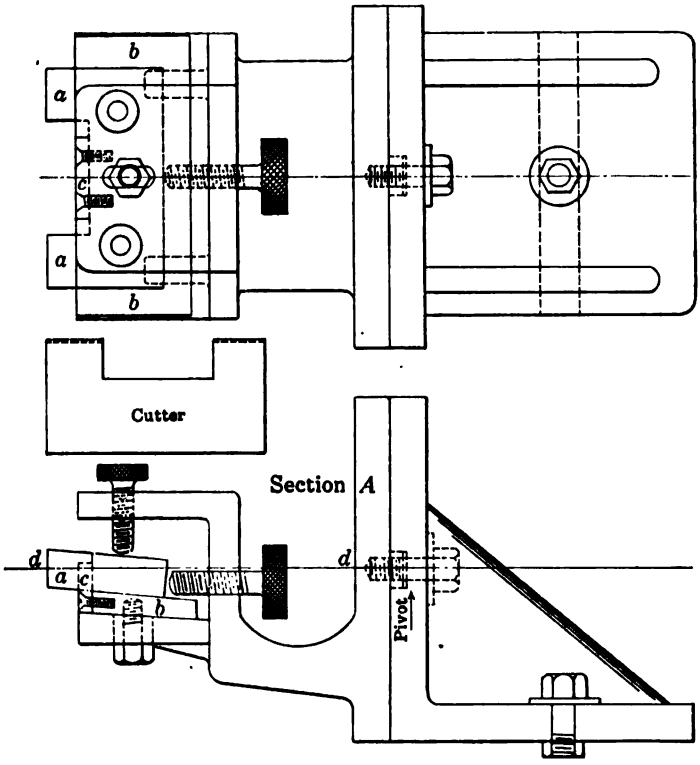
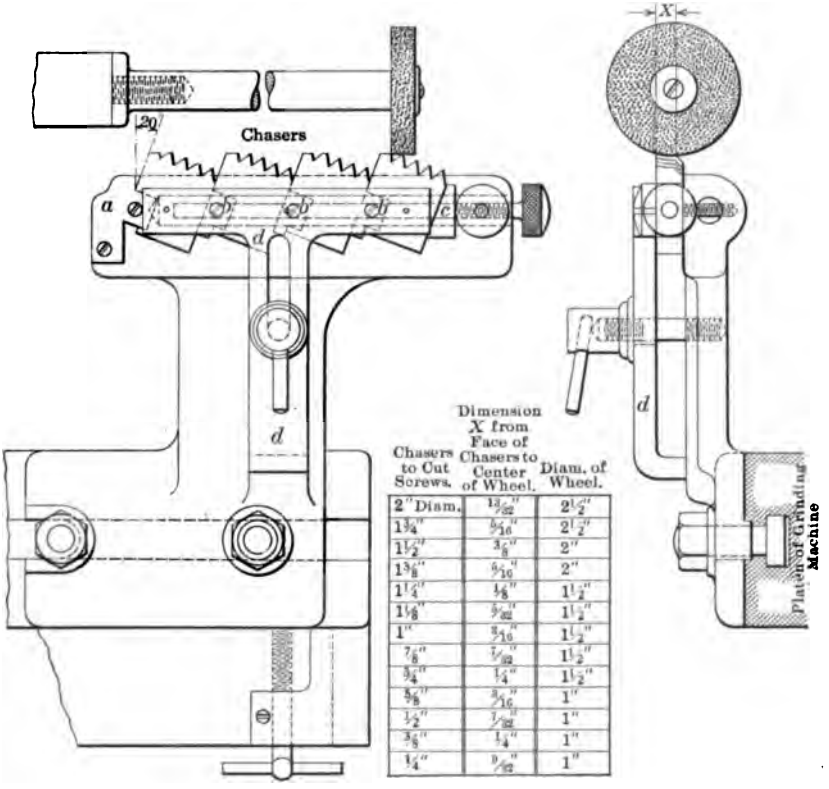


FIG. 240. A NEW FIXTURE FOR GRINDING BORING BAR AND COUNTERBORE CUTTERS.

CHASER GRINDING ATTACHMENT

Users of automatic die heads know that where the chasers are ground in the throat it is very important that all chasers in a set should be ground exactly alike in order that each do its share of the work, and that they should be ground as slightly as possible to the end that the life of the chasers be prolonged. Many fixtures have been devised to accomplish this object. Some of these have the holder arranged to hold only one chaser, which seems a defect inasmuch as some one of a set of chasers will always need more grinding than its mates, so that it will often be necessary to replace them on the grinder in order to take off just a little more. The fixture here shown in Fig. 241 is designed to receive a full set of chasers which are ground at a single operation, each one resting

against a block exactly as it does in the die head. The first of these blocks *a* is solidly fixed at an angle of 20 degrees; the other blocks *b b b* are free to slide on a tongue in a slot in the extension plates and take their positions according to the thickness of preceding chaser and assume the same angular position as the fixed block, being forced against it by pressure of the screw in distance piece *c* which also has a tongue to fit the slot and prevent its sliding out of position. This block *c* is longer to accommodate smaller chasers. The machine



Chasers to Cut Screws.	Dimension X from Face of Chasers to Center of Wheel.	Diam. of Wheel.
2" Diam.	1 3/32"	2 1/2"
1 3/4"	5/16"	2 1/2"
1 1/2"	1/8"	2"
1 3/8"	5/16"	2"
1 1/4"	1/8"	1 1/2"
1 1/8"	3/32"	1 1/2"
1"	5/16"	1 1/2"
7/8"	1/32"	1 1/2"
3/4"	1/4"	1 1/2"
5/8"	3/16"	1"
1/2"	1/32"	1"
3/8"	1/4"	1"
1/4"	9/32"	1"

FIG. 241. GRINDING ATTACHMENT FOR DIE CHASERS.

is shown set up for large size chasers of an opening die head and as the small sizes are each 1/4 in. smaller, the distance piece *c* is 1 in. wider. The clamp *d* to hold the chasers in place has a leather face to secure tension on all chasers. This fixture as shown is an attachment to a regular grinding machine having platen movements in all directions.

The chart showing the height to set chasers above center of emery wheel and size of wheel to use has never been worked out on a scientific basis, but in practice gives good results.

GRINDING THREADING DIES

The sketch, Fig. 242, shows a method of preparing a threading die so that it can be ground without being split in two. A solid die when it becomes dull has to be split in order to get at the teeth to grind them, and this is not a very satisfactory way, as one cannot even then get an emery wheel small enough to go between the teeth. In order to avoid splitting some solid dies this new method

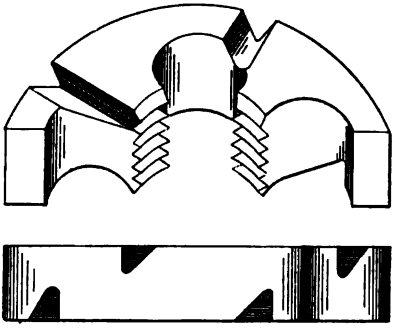


FIG. 242. DIE ADAPTED FOR GRINDING FROM BOTH SIDES.

was devised. By grinding the slots with a disk emery wheel it enables the cutting teeth to be ground down to about one-half the distance through the die, and by reversing this, the same operation can be performed on the opposite side, thus giving life to both sides of the die.

GRINDING A SNAP GAGE AND STRAIGHTEDGE ON THE CUTTER GRINDER

Figures 243 and 244 illustrate surface grinding work on the Cincinnati cutter grinder. The regular surface grinding attachment for this machine when mounted upon the table, as in Fig. 244, allows the work held in its jaws to be presented at any desired angle with the axis of the wheel head by making the necessary adjustments of the swivel vise, the table and the long slide.

The snap gage (Fig. 243) is held in the vise jaws and grinding is done with a cup wheel. The best results are obtained when the center of the work is the same height as the center of the spindle. By reversing the wheel on its spindle or by using a double-edge cup wheel which cuts on both sides, the opposite jaw of the gage may be ground. In this manner gages up to 13 in. may be ground without rechucking.

In grinding a straightedge or similar piece, the work is clamped in the manner illustrated in Fig. 244.

The end of the table is set to the zero mark on the graduated scale on the face of the long slide. The knee should be swung around to 1/2 degree off the 90-degree mark so that one side only of the wheel will come in contact with the work.

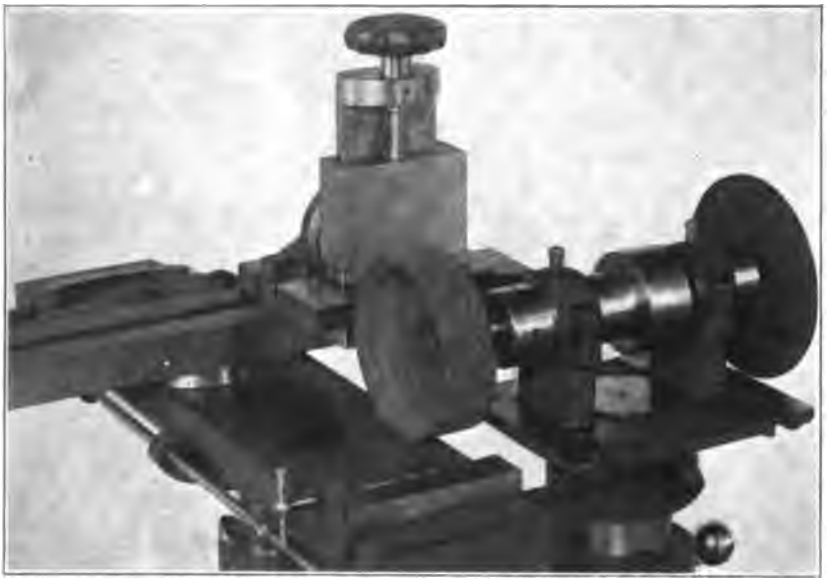


FIG. 243. GRINDING A SNAP GAGE ON THE CUTTER GRINDER.

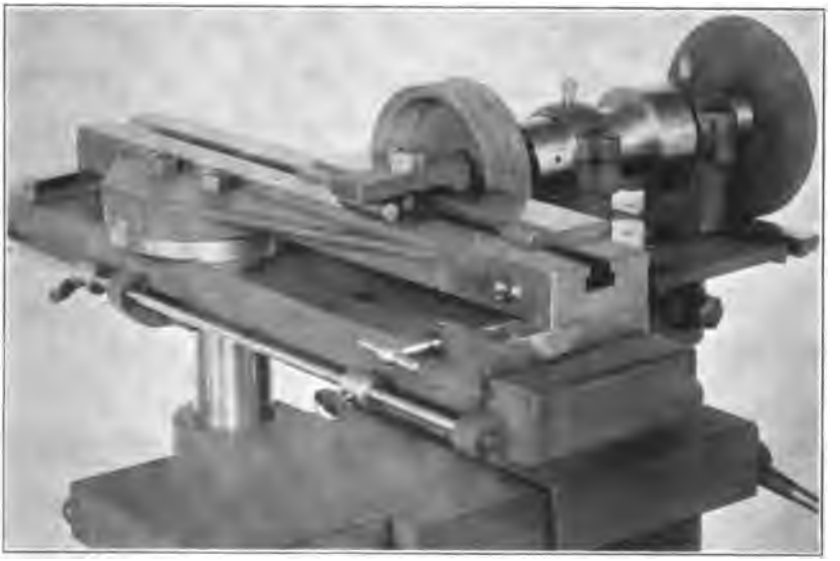


FIG. 244. GRINDING A STRAIGHT EDGE ON THE CUTTER GRINDER.

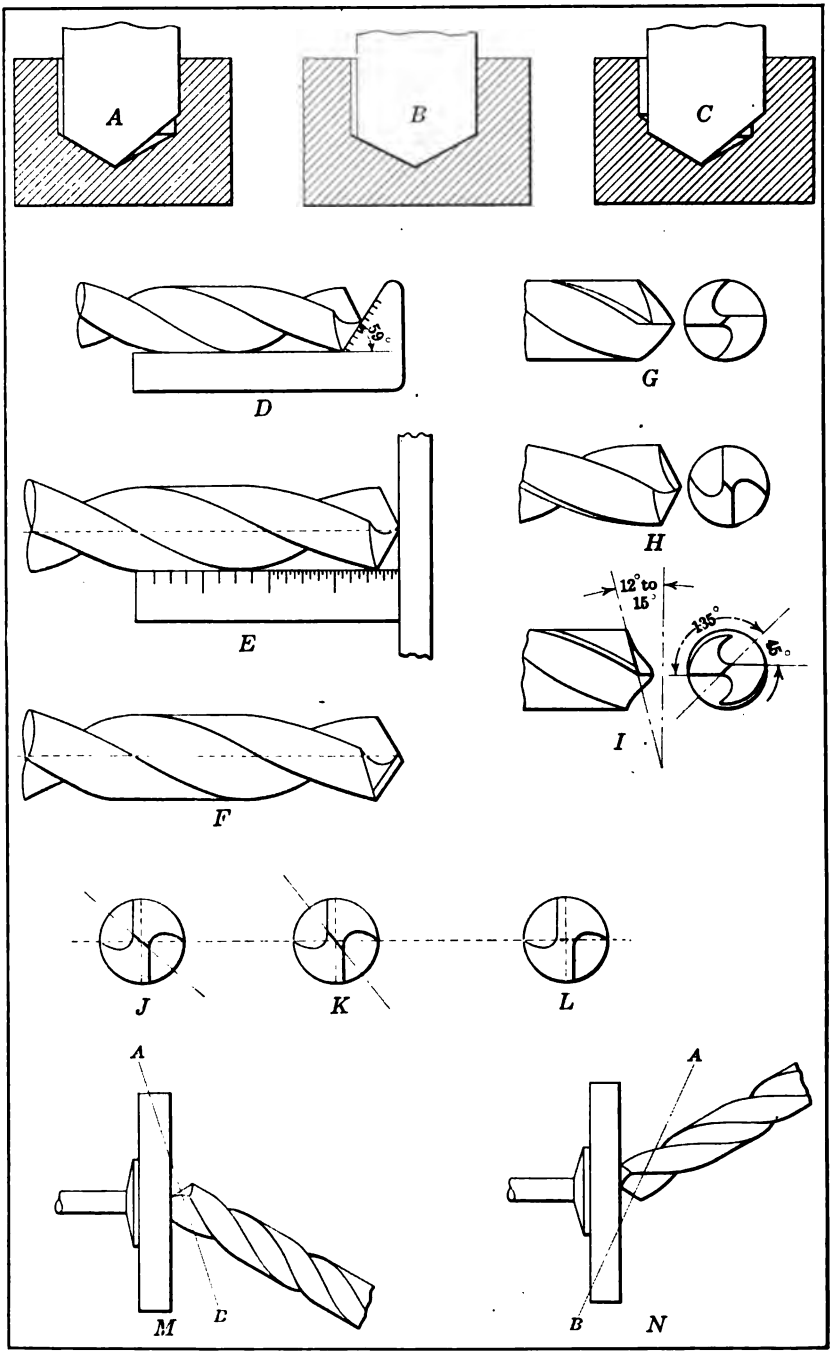


FIG. 245. DETAILS OF DRILL GRINDING.

SHARPENING TWIST DRILLS

Drills should be ground so as to cut the right size and with as little power as possible.

In order to have the drill in condition to cut the right size, the cutting lips must be of equal length and form equal angles with the axis of the drill. Both of these conditions must be observed or the drill will cut oversize. Thus in *A*, the point is central but the angles are not alike. In *B*, the angles are equal but lips are not of equal length. In *C*, the angles are unequal and the lips also. In all three cases the drill will cut oversize as indicated, and one lip will do practically all of the work, so that it will dull rapidly and require an extra amount of grinding to keep the drill in condition to cut.

GAGING AND MODIFYING THE LIPS

A gage like that shown in *D* will be an aid in getting the angles correct and in grinding the lips central. This gives the usual lip edge angle of 59 degrees. At *E* is shown a method of determining if both of the lips are alike, but it does not give the angle. *F* is a suggestion by Professor Sweet for relieving the drill back of the cutting edge, making it similar to a flat drill in this respect.

For drilling brass, or for any thin stock where the drill goes through, it is best to grind the cutting edge parallel with the axis of the drill. This does away with the tendency for the drill to draw into the work. *G* shows how this is done.

It is sometimes necessary to thin the point of the drill to get best results. This requires care in grinding but it can be done as shown in *H*.

THE PROPER CLEARANCE

The best all-round clearance is 12 degrees, though for softer metals 15 degrees can be used. The 12-degree angle referred to is at the cutting edge, but this should increase back of the cutting edge so that the line across the web will be 45 degrees with the cutting edges. This is important as it not only saves power but prevents splitting of the drill in severe service. The point of the drill should look like *G* or *H*. At *I* is the clearance angle and the right angles for the drill point.

The angle of 59 degrees has been mentioned as the usual one for the lip edge. Twist drills are customarily made so that their cutting edges are straight when ground to this angle. If the drill is ground to a lesser angle, the lips are left hooking and are likely to produce a crooked and irregular hole.

The grinding lines of the drill are placed slightly above center as in *J*, *K* and *L*, to allow for the proper angle of the point which indicates the extent of the clearance. Both *I* and *J* show the proper angle across the point or web, while in *K* the angle is too sharp and will cause the drill to cut rank. The angle in *L* runs backward and shows an entire lack of clearance.

MEASURING THE CLEARANCE

If the drill is placed as in *E*, and rotated with its point against the plane surface, the scale will indicate at once the amount of clearance, at the same time showing whether the lips are of equal length as already pointed out.

This question of proper clearance is a most important one, and it is of course impossible to grind a drill by hand so that the clearance will be just right.

A principle employed on some drill grinders to give the clearance to the lips is represented by *M* and *N*. Here the axis about which the drill swings in the grinding of the two lips is shown at *A–B* and it will be seen that the method results in grinding the lip behind the cutting edge, to the form of a truncated cone, the apex of which is at the point of intersection of the axis *A–B* with the wheel face. This gives a gradual increase in clearance from the outside of the drill to the center.

STANDARD SHAPES AND ANGLES OF LATHE, PLANER AND SLOTTER TOOLS—SELLER'S SYSTEM

The Tables 34 to 36, on pages 372 to 376, show the forms of lathe, planer and slotter tools with the angles given as standardized by Wm. Sellers & Co. Inc. and recommended by them for tools ground on their universal tool grinders.

WHAT CAUSES CHECKING IN FINE FINISHING STEEL TOOLS

The following difficulties are sometimes experienced with the checking of high speed steel cutters after grinding.

In grinding high speed and fine-finishing steel it is often found that milling cutters 4 in. or more in diameter, in which the sides have to be ground, will come from the grinding department checked. And if the cutter is sounded for cracks it will not have the clear tone that it had before grinding. These cutters will sometimes stand until they are worn out, or they may break at some of the checked points.

It is also found in grinding profile cutters that the shank will sometimes be checked in as many as ten or fifteen places and if given a light tap with a hammer will break like glass. The same cutters can be struck a hard blow before they are ground and they will not break.

There are also other things that tend to prove that the trouble is not in the hardening. Trouble with the alloyed water-hardening or fine-finishing steel develops in a similar way to that met in high speed steel. The difference is that the fine-finishing steel will be soft immediately under the wheel even with the water pouring on it, thus making it more difficult to understand the checkings. At times tools come from the grinding full of deep checks. These tools would stand most any test that might be given them before grinding and show no sign of being checked.

As a rule the question of tool grinding has hinged upon the question as to whether the grinding should be done dry or wet and many writers have gone deep into the discussion as though the *only* factor to consider was water or no water.

The tool grinding wheel commonly used is very hard and many suppose that the smoothness of the surface and fineness of the edge depends upon the use of fine grained wheels. It appears that few realize that a coarse grained surface and ragged edge is often caused by the abrasion of the chips of metal held between the fine grains of the wheel, and that a coarser wheel of the right grade will in many cases give a smoother surface.

Wheel makers as a rule furnish the grain and grade for tool grinding that will, in their judgment, best suit the customer, rather than the grain and grade which they know to be the best for the best results in grinding tools. In other words, the grain and grade of wheel for tool grinding is really fixed by the ideas of the average user of the wheels and it could not be otherwise in the nature of things; surely the user must obtain what he wishes or he will go elsewhere for his goods.

We have felt for years that there must come a change of view among users of tool grinding wheels, and we are pleased to note that the fact that trouble with grinding is due to error in selecting the wheels and not to the fact that the tools were ground with an emery wheel instead of a grindstone, or wet instead of dry, is coming to be known by the users of grinding wheels.

AMOUNT OF LUBRICANT TO USE

If the wheel is too hard or too fine the workman must crowd the work to get quick results, while with a relatively soft and coarse wheel run at about 5500 surface feet per minute, with about 25 gallons of good lubricant flowing on the tool and wheel face (both) every minute, quick results can be obtained without crowding. In fact the tool can be ground with a pressure so light that few men can be induced to make that pressure light enough to prevent digging into the wheel; thus, most people who try such a wheel spoil it in a short time by over crowding.

It is coming to be realized that lubricating the wheel to preserve the cutting edges and thus prevent undue heating is quite as important as cooling the tool after it is heated; in fact, it is the cooling of the tool after it is heated that has much to do with checking, yet it is also true that the sudden heating of the surface before the interior is heated causes checks. Both are caused by crowding, and crowding is made necessary by a hard or a dense, fine wheel. Did you ever try to cut fast and deep with a very fine tooth milling cutter? If you have, you know that a great amount of heat was generated and this because the chips filled the spaces between the teeth full of steel so that the friction of the steel in the teeth against the work became very great.

Now, with a fine wheel that does not wear away too fast there is little room for the chips to escape and the result is the friction of the steel against the work, which causes heat. With a coarse wheel and a bond so hard that it does not wear enough between the coarse particles when these particles are worn down near to the bond, there is no room left for chips. With a still harder bond the particles of grit finally wear down to exactly the same radius as the bond which produces what we call glazing.

These facts have long been known to many, but the world is large and it is difficult for anyone to realize, except by personal experience, which is too often misleading because we do not fully realize all the conditions.

Too little time, money and thought generally go into the machines and wheels for tool grinding. Makers of both machines and wheels are, as a rule, glad to give advice from their long experience which can hardly fail to be of value in many shops and should be taken advantage of.

CHAPTER XIV

GRINDING STEEL AND IRON CASTINGS[1]

The grinding of steel and iron castings is of such importance that the foundry man is giving much attention to the grinding wheels and the equipment on which they are run.

This article considers first the machines by means of which steel castings are ground, touching on the important features and adaptability of the different types; then the grains and grades used and the factors which influence them and present methods of measuring wheel efficiency.

TYPE OF MACHINE USED

The types of machines used for grinding steel castings may conveniently be divided into the following groups: Swing-frame, floor stands, and special machines for semi-precision work.

Swing-frame grinders are best adapted where is it more convenient to move the wheel over the casting than the casting over the wheel. Such machines must be free to swing back and forth, sideways, up and down, and it must also be possible to turn the wheel at an angle. There are three methods of driving the wheel, as follows: belt drive from main lineshaft through countershaft, belt drive from individual motor, and wheel spindle direct coupled to armature of motor. Occasionally, one will see a swing-frame machine with a rope drive, but it is believed that this method has been discarded for belts on all machines made to-day. The belt drive from the main lineshaft through a countershaft is rapidly going out of use and giving place to individual motor drives. Suppose it is only desired to run one machine in a row of ten or more: with the main lineshaft drive, it is necessary to run the big motor which uses as much power for one machine as for ten. At present, the majority of these motors are constant speed, but grinding wheel users are waking up to the fact that in order to get the highest efficiency out of the wheel, it is necessary to keep the surface speed constant as the wheel wears down. This necessitates the use of a variable speed motor which can be speeded up proportionately as the diameter of the wheel becomes smaller.

SWING-FRAME MACHINES

Swing-frame grinding machines may further be divided into two sub-classes, as follows: machines which have the wheel in the center of the frame, and outside the frame. From the operator's point of view, the machine which has the wheel

[1] From an article by R. G. Williams (Norton Company Dept. of Tests), in *Grits and Grinds*.

situated in the center of the frame is the most desirable to operate, since the weight of the machine is well balanced. But it is often found desirable after wheels have worn down to small diameters to use a machine which has the wheel mounted outside of the frame. The reason for this is that on some kinds of grinding, for instance, the face of a draw-bar, if the wheel is situated in the middle of the frame after it is worn down to a certain size, it is found that the frame of the machine knocks against the sides of the bar. By using a wheel which is mounted on the outside of the frame, this difficulty is overcome, since it is possible to use smaller flanges. However, with this outside type of mounting, the weight of the wheel must be counter-balanced by weight on the opposite side of the machine, and the operator cannot use his full weight on the wheel during grinding, as this would tend to tip the machine over sideways. A special type of machine is mounted on wheels, making it possible to move the machine from one place to another. Sometimes it is necessary to grind a very large casting, such as a 15-ton ladle. In order to properly accomplish a grinding operation of this kind, it must be possible to move the machine used through a greater distance than is possible with the ordinary swing-frame grinder, and it is here that a machine mounted on wheels is well adapted.

A prominent manufacturer of swing-frame grinding machines recommends a 4-in. belt leading to the wheel spindle. While this width of belt may serve in many cases, in order to reduce to a minimum, the possibility of wheel slippage, a 5-in. belt should be used.

The use of protection hoods on these machines is becoming more and more universal[1]. Once in a while it is found that wheels are carelessly mounted on swing-frame machines, but undoubtedly all users of wheels are learning the importance of proper mounting. Where straight flanges are used they are almost always properly relieved, but protection flanges are very seldom found relieved.

All of the swing-frame machines made to-day have two stout handles running out in front, by means of which the grinder conveniently operates the machine. However, very few of the machines in use to-day are of recent make and machines are found without any handles at all, the operator simply grasping the yoke; or two small handles extend out from the yoke and the machine is operated by standing at the side.

FLOOR STANDS

We are all familiar with the different types of floor stands and this type of machine will only just be touched upon. For convenience, these machines may be divided into the following groups: Belts driven from individual motor, individual motor direct coupled to the spindle of the machine, and belt drive from main lineshaft.

[1] It is very important that such machines have substantial hoods, no matter what type of flange is used, thus preventing possibility of pieces of the wheel flying if it breaks outside of its flanges. A protection hood for the swing-frame machine is illustrated on page 176, of Chapter VIII.

In like manner, the use of variable speed motors is rapidly becoming as popular as with swing-frame machines. There are several types of floor stands now which have the motor attached and it makes a very convenient machine in operation.

Where the castings to be ground are 20 lb. or lighter, they are generally supported on the rest, but where the castings are heavier, the practice is to hold them in a chain lift, the use of the rest being done away with in this instance.

There are as many types of protection hoods on floor stands as there are makes of machines, and any type can be called good which affords proper protection to the operator.

The use of dust hoods is rapidly coming into favor and it is found that the ordinary protection hood can be made to serve as a dust hood by enclosing the sides and connecting with a suitable exhaust system.

SPECIAL MACHINES

Special machines that are used for semi-precision grinding are of the lathe type, the boring mill and the shaper types. These are used principally for large, heavy castings which must be ground to approximate size, namely, within 1/32 in. The particular field for these machines is in grinding alloy steel castings, it being impossible to machine them.

SELECTION OF WHEELS—SPEEDS

The grain and grade of wheel best adapted to grind steel castings will naturally vary with the conditions of the particular proposition in question. We have the same general rules holding true as with other types of grinding, namely, machines in good condition can make economical use of a softer grade of wheel than a machine which is of light construction and has been used roughly. Swing-frame grinders and floor stands carry wheels usually from 18 to 24 in. in diameter and from 1 1/2 to 3 in. thick. 6000 surface feet per minute is the common speed, although 5000 surface feet per minute is still used in a good many places. Users are rapidly learning that it is safe and more convenient to run all the wheels at 6000 rather than 5000 surface feet per minute for grinding castings.

The size of casting usually ground on swing-frame machines will vary in weight from 50 lb. up to 200 lb. and over. The size of the casting naturally influences the grain and grade to be used, for the following reasons. It is very seldom that the casting is held firmly, so that is cannot vibrate during grinding, and a large casting, even if just placed on the floor, will absorb more vibration, therefore, jar the wheel less than a smaller casting. It is a common practice to place medium castings on planks on a truck while being ground. Such a foundation

is very springy, and it will be found that a harder grade of wheel must be used under these circumstances than if the castings were held firmly. The nature of the operation will also influence the grain and grade to use. If the operation consists of simply removing sharp fins and scabs, a harder grade of wheel must be used than if the operation requires the casting to be ground to rough gage limit. As will be seen, this is due to the fact that where the casting needs to be ground to a rough gage limit, more or less surface grinding must be done after the fins and burrs are removed.

USE OF DRESSERS

The question of using dressers seems to be one on which it is hard to agree. Some wheel users say: "We gave up the use of dressers for a time and we got into all kinds of trouble; the wheels ran out of truth and our production fell down, so we gave back the dressers and let the men dress the wheel whenever it is necessary." The result is that whenever the operator thinks his wheel is getting just a little dull, he immediately starts to wear it out with a dresser.

On the other hand, customers have discarded the use of dressers on snagging wheels, and while they may have experienced some difficulty at first, they soon found that the men kept the wheels true, maintained production at its proper level, and the wheels lasted longer.

WHEEL EFFICIENCY

Unfortunately there are still a lot of factories which consider that the number of hours a wheel lasts is the only way to look at its efficiency. In other words, they take no consideration of the daily production of the wheel and consider life of wheel of prime importance. Such unfortunate conditions are due in some places to a lack of care on the part of the "powers that be," and in others, conditions are such that it would be impracticable to try to measure the efficiency by any such means, say, as tonnage produced per day, for sometimes a wheel will be grinding very small castings and at another time very large castings, both of which might require exactly the same amount of material to be removed.

The wheel records, if any are kept at all, as reported by the average user, are also open to criticism.

This matter is usually considered to be of such minor importance that it is entrusted to a boy or a low-priced man.

Wheels of the following grains and grades are most commonly used in grinding castings:

Large steel castings: 10 to 14, grades S and harder.

Small steel castings: 20 to 30, grades P to S.

Large malleable iron castings: 14 to 20, grades Q to U.

Small malleable iron castings: 20 to 30, grades P to S.

Large cast iron castings: 16 to 24, grades Q to U.

Small cast iron castings: 20 to 30, grades P to S.

For semi-precision work, grains 14 to 16 and grades O to Q will usually give satisfaction.

The ratio between daily production and piece rate and wages must be carefully considered. A very hard wheel will give a very low grinding cost per ton,

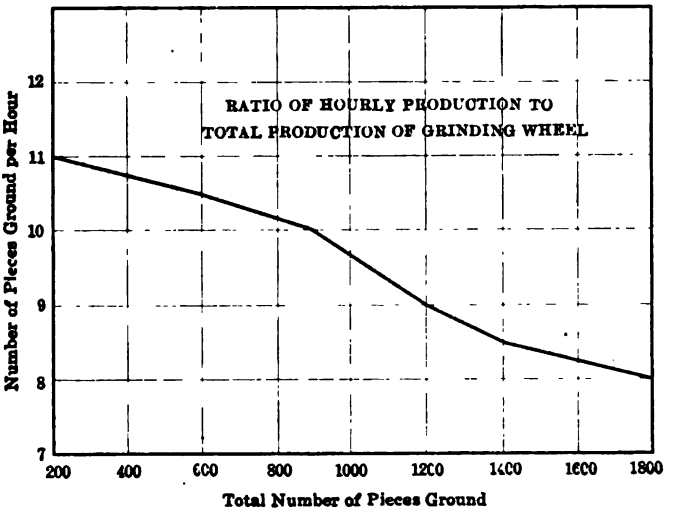


FIG. 246. CURVE SHOWING RATIO OF HOURLY PRODUCTION TO TOTAL PRODUCTION OF GRINDING WHEEL.

but the hourly production or daily production will fall below the point where the grinder hand can earn a fair day's wage.

The curve sheet reproduced in Fig. 246, gives the ratio of hourly production to total production of grinding wheel. It will be seen that a hard wheel will last longer and therefore grind more pieces than a softer one, but the number of pieces ground per hour will be less.

POINTS THE FOUNDRY MAN SHOULD KEEP IN MIND FOR ECONOMICAL PRODUCTION

(1) Am I using the right abrasive and the right grain and grade of that abrasive?

(2) Do I personally know that accurate grinding records are being kept?

(3) Can my monthly tonnage stand the use of harder wheels which will somewhat cut down the hourly production, but reduce total grinding costs?

(4) Should I use softer wheels to get the product out faster?

(5) Are the machines in use of heavy rigid construction? Are they kept in

first class condition? Are the belts wide enough and kept in proper tension? Are wheels run at the proper speeds?

(6) Are the grinder hands protected from accident by the use of suitable hoods?

GRINDING BRASS, BRONZE, ALUMINUM AND OTHER ALLOYS

Tests made by the Norton Company show that the alloying of zinc, tin, lead, iron and manganese with nickel and copper, makes very little difference in their effect on the grinding wheel.

To develop a wheel that will successfully grind brass, bronze, aluminum and other alloys has been one of the most difficult problems that grinding wheel manufacturers have endeavored to solve. Greater success has been obtained in grinding these materials since the development of modern electric furnace abrasive materials.

The information which follows was brought out in a paper by George W. Thomson, the company's representative in a territory where there are a great many foundries and manufacturers using these alloys.

GRINDING BRASSES AND BRONZES

Brass and bronze were forerunners of all casting alloys. It is now necessary, however, to distinguish between numerous kinds of brass of high and low zinc content, red and yellow, bronze, naval brass, malleable brass, aluminum brass and many others. The term "bronze" was formerly employed to indicate an alloy, the only constituents being copper and tin—copper predominating; but in recent years almost every combination of metals possessing strength and tough ness have been termed bronzes.

In trade circles, brass is generally understood to mean an alloy of two-thirds copper and one-third zinc, but in everyday foundry practice it is found to contain other metals besides copper and zinc. The copper content may vary from 60 per cent to 88 per cent of the whole mixture; likewise the amount of copper and tin in bronze varies.

While very desirable qualities for mechanical purposes are obtained by the alloying of zinc, tin, lead, iron manganese and nickel to copper, with but two exceptions the resulting alloys show very little difference in their action on a grinding wheel of the correct grain and grade. The exceptions are nickel bronze and bell metal—two of the hardest alloys. These can be ground with fair success on the same wheel as the other alloys, but where the quantity of this material coming through will warrant it, it is recommended that a special wheel of correct grain and grade be used. The content of nickel in nickel bronze and tin in bell metal is sufficient to make them very hard. On nickel bronze a wheel made of Crystolon, grain 24, grade Q gave very good results; and for bell metal,

a wheel made of the same material but of a little harder grade. Nos. 24 and 30, grade R wheels are recommended. Comparatively thin wheels are, as a rule, used on bell metal work and the corners are used to quite an extent. The work is, therfore, severe on the grinding wheel.

An experience in grinding brasses and bronzes with two Crystolon wheels will be of interest. A 14×2 in. 24-Q and 14×2 in. 30-P were placed on the same arbor in one of the largest commercial foundries in Connecticut and used 10 hours a day every day in the week except Sunday on all shapes and kinds of brasses and bronzes. These wheels were watched very carefully—almost daily—and no noticeable wear of the wheels could be found for several days. After running 8 months they measured 12 1/2 in. diameter. The dresser had not been used on either wheel during this time. The 30-P seemed to do a little the better; the 24-Q not working quite as free and clean.

ALUMINUM

This alloy is ductile, malleable and tenacious. In the automobile industry, where light castings are important, alloys containing aluminum and zinc are largely used. In this class of work Crystolon elastic wheels grain 36, grade 4, have given very satisfactory service. This wheel was found to remove the metal faster and load the slowest of all wheels tried, and at the same time gave a good surface. Grade 5 elastic process, also did good work.

NICKEL BRONZE

When experimenting on this alloy, the same wheels were used that were tried on the brass, standard bronze and aluminum.

A feature to be noted, on account of its usual absence in connection with grinding brasses and bronzes, was the formation of very dull red sparks which were quite dense just under the point of contact. These sparks became invisible at approximately 4 in. from point of contact. All wheels heated the work very quickly and felt "hard"; in fact, this bronze appeared much harder than any of the other brasses or bronzes. The wheels all loaded about equally. The 24-Q and 30-P wheels were the best cutting wheels, the 30-P doing a trifle the better work although both were about equal.

GOVERNMENT BRONZE

This alloy also gave off a very dull, red spark, but was not as noticeable as in the case of nickel bronze. The 30-P was the best wheel as it took hold well, did not load half as much as the 24-Q, although used more, nor did it feel as hard as did the 30-Q and 36-P. A characteristic of these wheels was that the alloy loaded the wheels in small spots less than the size of a pin-head.

In regard to the loading of wheels, experiments showed that aluminum loads more than the other alloys referred to in this article; phosphor-bronze next, Standard Foundry bronze and Government bronze about the same, and nickel bronze the least. All wheels tried were—14×1 1/2×1 1/2 in. and run at 1360 r. p. m., or 5000 surface feet per minute.

A 30-P Crystolon wheel is recommended for the snagging of all kinds of brasses and bronzes in ordinary commercial foundries. This does not apply, of course, to foundries that melt up one kind of metal for a special purpose. In cases of this kind, it would undoubtedly be policy to test out—say 24-P, 24-Q, 30 -P and 36-O Crystolon to determine which is best adapted for the work.

As Crystolon is practically the same as carborundum, the same conclusions apply in either case.

CHAPTER XV

BUFFING AND POLISHING

The old strapping machine, consisting of two flanged pulleys carrying a canvas belt loaded with glue and abrasive on the outer side, has long been used for finishing irregular surfaces, especially on brass work. It is often called a strapping or strap buffing machine. These machines are modified to suit special conditions for such work as cutlery polishing.

The straps or grinding belts run at from 2000 to 2500 ft. per minute in most cases. The later development of this type of grinding is in the belt grinder as shown in Fig. 88. In some of the later types of machines the belt is of emery or other abrasive cloth, carefully cemented into an endless belt and run at about 7000 ft. per minute.

At the point where the grinding is done, the belt runs over a flat metal plate which supports both the belt and the work and produces remarkably flat surfaces. These are adapted to a variety of work, being often arranged to automatically move the piece to be ground so as to give the desired contour to the ground surface, the operator simply loading and unloading the fixtures made to hold the work. Very accurate results are claimed for grinding flat work, such as collars and plates, to a specified thickness, two or more abrasive belts being used in conjunction to secure accuracy and economy. The belts usually run on top of or over, a specially prepared leather belt which acts as a cushion.

Paper belts have been used but cloth gives the best results. It would seem as though they would be torn by sharp points on the metal, but the very high speed grinds even a point of hardened steel before it can penetrate the belt in the least.

BAND POLISHING MACHINES

Polishing wheels were formerly of wood with the abrasive carried on a leather strip or band pegged to the wheel. They were covered with glue and rolled in emery or other abrasive.

The later practice is to use a wheel of a steel casting about 12 in. in diameter and 2 1/2 in. face. The face is covered with a strip of cloth carrying the abrasive so that they can be changed from one grade to another or renewed when worn, with very little difficulty.

The grinding bands are graded as follows:

No. of cloth:	00	0	1/2	1	1 1/2	2	2 1/2	3	3 1/2
Grade of abrasive:	Flour	120	90	80	70	60	46	36	24

Polishing machines are made in two styles, one to be used while standing and the other sitting down. They are designated as "standing" or "sitting" machines. Sitting machines have spindles 32 in. from the floor and standing machines, 42 in. from the floor.

A 12-in. wheel is run about 1850 r. p. m., making a surface speed of about 5500 ft. per minute. With an individual motor three horse-power is allowed for one of these machines.

PREPARING POLISHING BELTS

The engraving Fig. 247, represents the method used in a shop for coating polishing belts. The belt is a non-elastic web, the joint being sewed on a machine. Ten or a dozen of the belts are covered at a time. They are placed, one at a time, on a small pulley with a flange and run on a very much larger pulley or an old polishing wheel with a face a trifle narrower than the width of

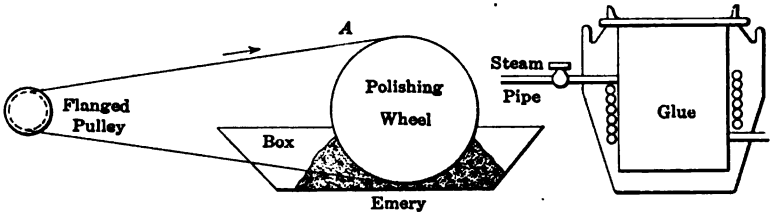


FIG. 247. PREPARING POLISHING BELTS.

the belt. This allows the glue and emery to cover the edges of the belt. A boy stands at *A* and applies the glue as he pulls the belt toward him, as indicated by the arrow. The other boy stands at one side of the box or trough and keeps the emery heaped upon both sides of the wheel face, so that by forcing the wheel through this pile the emery is applied with considerable force. The box is long enough to catch any emery that falls off. The belts are then hung on round pegs to dry. These belts are used to polish the rings of scissors and forceps, and when in use are run between a large double-flanged pulley and a small flat pulley, so that if the work should catch, or the polisher's hand, the belt runs off the small pulley.

As to the glue, a medium grade is used, which costs 22 cents, ground. This is not allowed to boil, and it is made fresh each time. The glue pots are attached to live-steam pipes by a copper tube made into a coil in the water pot; the glue pot fits into the center of this. Keep the brush clean.

FACTS ABOUT POLISHING[1]

There are many varieties of polishing wheels in use, the principal kinds being known as wooden wheels, compressed wheels, canvas and muslin, sea-horse and felt wheels. To equip a polishing room with the right wheels requires the assistance of a polisher who has had a wide experience in polishing and is familiar with the various methods employed as well as the best abrasives. For good work, and economy in abrasive, glue and labor cost, wheels and methods must be selected to suit the work.

WOODEN WHEELS

A few years ago, the wooden wheel covered with leather and turned to fit the piece to be polished, was universally used. At the present time, the wooden, leather-covered wheel is used largely on flat surfaces and on work where it is necessary to maintain good edges. When this kind of a wheel is made with a double coating of leather, it makes a first class finishing wheel.

COMPRESSED WHEELS

Compressed wheels, or wheels having a steel center are made with surfaces of leather, canvas or linen. Many tool shops are equipped with these wheels exclusively. They answer all purposes and are safer and more economical than wooden wheels.

They are also used largely on cutlery and for polishing chilled plows. The compressed wheel is of strong construction, is very durable and easily kept in balance.

CANVAS AND MUSLIN WHEELS

Canvas and muslin wheels are used extensively for polishing stoves, shovels, plows, brass, cast iron and steel. For roughing out and dry fining on irregular pieces, they have proved very satisfactory. They hold the abrasive well and require no washing off as they can be cleaned with a buff stick or an abrasive brick.

Many concerns, such as plow-, shovel- and hoemakers, buy the canvas and muslin and make their own wheels.

SEA-HORSE WHEELS

Sea-horse wheels are very expensive, most concerns buying the hides and making their own wheels.

Where a high-grade polish is required, there is probably no wheel which can compare with the wheel made of sea horse. They are largely used on guns, pistols and cutlery.

[1] W. P. Ford, in *Grits and Grinds.*

FELT WHEELS

Felt wheels are largely used by stovemakers for finishing surfaces. Bull neck wheels are also used for this purpose.

The felt wheels are made from white Spanish and Mexican felt and are extensively used for finishing on certain classes of work.

CARE OF POLISHING WHEELS

Polishing wheels should be kept in perfect balance and running true at all times. A wheel out of balance wastes time, glue and abrasive, and will not do as good work.

The most efficient glue and the best abrasive are the cheapest in the long run.

The glue pots should be kept clean and the glue properly cooked before using.

It is also important to heat the abrasive before applying.

The wheels should be kept properly cleaned and thoroughly covered with the abrasive.

The wheels should be selected for the particular work the same as in grinding and only the wheel best adapted should be used at all times.

Care in the selection of wheels, glue and abrasives means a greater saving in the polishing department than many realize. It secures not only a better quality of work but more of it.

When considering a change in abrasives, the cost of the abrasive itself is not the only point. The cost of labor, glue and wheels as well as the difference in production and finish of work, should be carefully considered.

POLISHING OPERATIONS

Polishing operations are usually divided into three classes: roughing, dry fining, and finishing or oiling.

The abrasives used for roughing usually run from numbers 20 to 80. For dry fining, from numbers 90 to 120. The numbers used for finishing run from 150 to XF.

For both roughing out and dry fining, the polishing wheels should be used dry. For finishing, the wheels are first worn down a little and then oil, beeswax, tallow and similar substances are used on the wheel. This, together with the abrasive, brings up a fine finish.

SPEED OF BUFFING WHEELS

Wood, leather covered	7000 ft. per minute.
Walrus	8000 ft. per minute.
Rag wheels	7000 ft. per minute.
Hair-brush wheels	12,000 ft. per minute.
Ohio grindstone	2500 ft. per minute.
Huron grindstone	3500 ft. per minute.

CHAPTER XVI

MAGNETIC CHUCKS, SPECIAL CHUCKS, MANDRELS AND DRIVERS

Magnetic chucks have come to be a very necessary part of the equipment of any surface grinding machine, whether plain or rotary. Credit for these belongs to O. S. Walker of Worcester, whose first patent was granted on July 21, 1896. These are now being made by others.

Before their coming it was customary to bed thin work in wax on the platen of a grinder in order to finish the flat sides. Other flat work had to be held in "fingers" on special fixtures, and on account of their being very thin and easily sprung, it was difficult to secure really accurate work.

The magnetic chuck holds the thinnest pieces of iron or steel firmly, draws down any slight spring in the work and prevents springing when strains are released during the grinding operations.

The chuck face is divided into magnet poles, separated by babbit or other non-magnetic metals, and coils of insulated wire form these into electromagnets when current is applied. For rotary work, the electric current is supplied by brushes running against insulated contract rings on the outside. Current can be supplied from any incandescent lamp socket on a direct current circuit.

Alternating current cannot be used.

A No. 0. chuck having a face 10×14 in. uses about one-half as much power as a 16 candle-power lamp. A No. 1 1/4 with a face 12×6 in. takes the same current as a 16 candle-power lamp.

Chucks are made with plain and duplex bases and arranged for straight and taper work.

Figure 248 shows a few adaptations of the magnetic chuck for holding work. The alining strip *M* in No. 1, is on the back of the chuck for squaring the work against. The edge of *G* just matches this so that the two form a squaring device as shown. No. 1 shows plain work that is easily held. In No. 2 the lower edge is not square and the long side *A* must be out so that the magnetic pull on the angle side, holds the piece against the squaring edges.

In No. 5, where a number of pieces are held at one setting, it is sometimes desirable to lay strips of non-magnetic materials, such as brass, or pasteboard in between them. In this way the magnetism of the chuck seems to get an independent grip on each piece. Sometimes, on heavy work, an adjustable finger as at *N*, is set against the last piece or row of pieces.

No. 6 shows another form of squaring device, which is itself held in place by the magnetism of the chuck.

DEMAGNETIZING THE CHUCK AND THE WORK

Iron and steel in contact with magnets retain some of the magnetism, which is sometimes more or less of a nuisance in getting small work off the chucks.

To overcome this the chucks are often furnished with a duplex or demagnetizing switch, which simply reverses the direction of the current and when this is done a few times the magnetism will disappear and the work will be easily released.

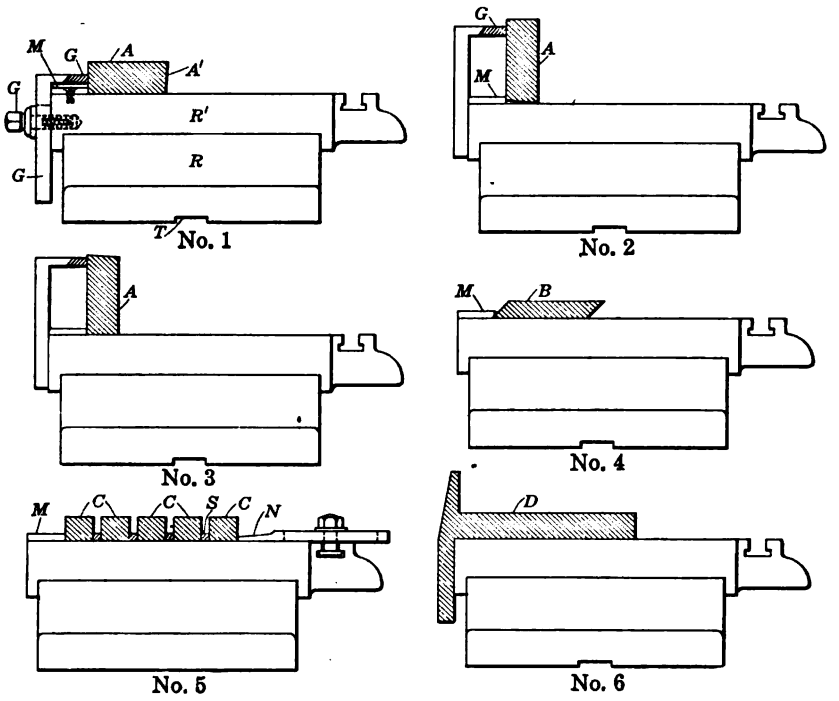


FIG. 248. BACK RESTS FOR MAGNETIC CHUCKS.

This does not demagnetize the work, but demagnetizers are made for this purpose. These are only necessary where the remaining magnetism is objectionable in the work itself. These are sometimes arranged to be worked automatically from the countershaft.

Magnetic chucks are made for use with water, but in most cases require a current of air to be blown through the chuck to prevent the entrance of water and the formation of moisture in the chuck interior from the constant heating and cooling of the coil chamber. Some of the later chucks do not require this.

ARRANGING JIGS ON MAGNETIC CHUCKS

In Fig. 249 will be seen an idea of how magnetic jigs can be arranged on the chucks. The work *W* is all in outline in each case. The holding pieces are

N and *P*, negative and positive, separated by non-magnetic materials *I*, and are air-gaps in the case of No. 2 to hold an angular piece by each leg.

A round bar can be held in *V s* as in No. 3. In No. 4 the central piece is postive and there are two outer, negative poles.

As an example of the way in which small and thin pieces can be handled in some such way is shown in Fig. 250. The disk *J* not only makes it easy

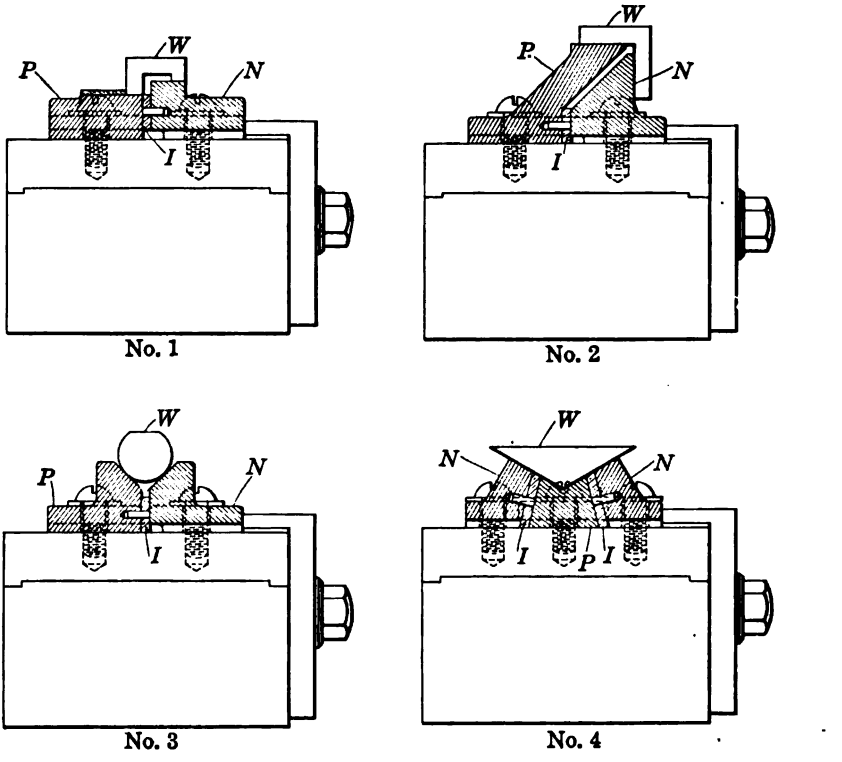


FIG. 249. MAGNETIC JIGS.

to locate the rings *I* so as to be firmly held and also assists in holding the work. The whole plate being attracted to the chuck acts as a locating disk and anchors the pieces against any side strains. These plates can also be made to hold small stampings which are too small to be held in any other way.

It is well known that it is only the small or thin work which is hard to hold. By using this perforated disk, or any similar device, the combined holding power of all the pieces assists in holding the separate ones. In some cases, a loose ring only is provided which encircles all the pieces of the work, while in others, a ring with internal teeth or notches is used to locate the work. These disks or rings can be removed with the work and remounted without loss of time.

HINTS FOR USING MAGNETIC CHUCKS

The chucks should not be taken apart.

Nothing but iron or steel can be held on the chucks.

The holding power depends on the amount of work surface in contact with the chuck.

Work can be held on edge by using adjustable back rest.

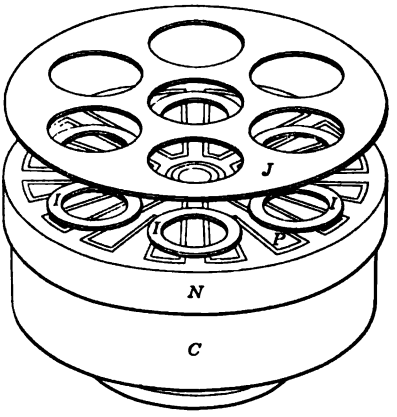


FIG. 250.

Very thin work can be held for grinding on the edges by laying it against the back rest and backing it up with a parallel strip.

Thin work will not hold as well as thick work.

In packing a number of small pieces on a chuck at one setting, it is better to separate them a little with strips of non-magnetic material.

Do not plug up the vent holes in the chuck.

Keep water away from the switch, the brushes and the interior of the chuck.

Magnetic chucks do not take the place of all other chucks.

Do not use water on chucks except where they are made for it.

Chucks are usually wound for 110 or 220 volts *for direct current only*.

A number of chucks, mandrels and driving devices of a special nature are shown by the accompanying engravings.

DRIVING WORK FROM THE END[1]

In grinding straight, cylindrical work, it is customary to grind up as close to the driving dog as possible, then reverse the shaft, fasten the dog on the other end and grind the short end that remains where the dog had been. Those who have had much production grinding to do, know how difficult it is to grind this

[1] R. J. Spence.

short end concentric with the other ground portion, on all work except short, rigid pieces.

The accompanying sketches show an end-driving dog, wihch has been used successfully for some time. The figures given are those required for a dog used on a 10-in. Norton plain grinder. The same style, however (of course, with changes in dimensions), can be used on any grinder or lathe.

FIG. 251. THE ASSEMBLED DOG.

The assembled dog, with its special center, is represented in Fig. 251. *A* is the dead center; *B* is the part that revolves on the center; *C* is the driver and fits into the slot on the face-plate of the headstock; *D* is the driving pin. A small piece of work is shown on centers with the driving pin engaged in a hole drilled to receive it. The dotted lines represent a much larger piece of work with the driver swung around to engage the hole.

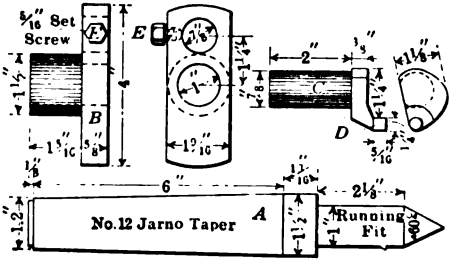


FIG. 252. DETAILS OF THE DOG.

This illustrates the wide range of the dog, but naturally a small driving pin limits the range to small work. The diameter of the pin should be proportionate to the diameter of the work. The set-screw *E* binds the driver in place when once set, and also permits a horizontal adjustment in case the center holes in the work are not all of the same depth. The driving pin should be a trifle smaller than the hole. The dog in detail is shown in Fig. 252. Figure 253 is a drill jig

for drilling the holes in the end of the work. By using this jig duplicate holes may be obtained, so that the driving pin will not need to be adjusted for each piece, provided that, in setting, enough clearance is given the driving pin by the horizontal adjustment to allow for the variation in the depth of the center holes.

The figures here given limit the size of the work taken by the jig to small diameters. A good plan is to have a longer jig that would take in both large and small diameters, with several loose bushings for different diameter holes.

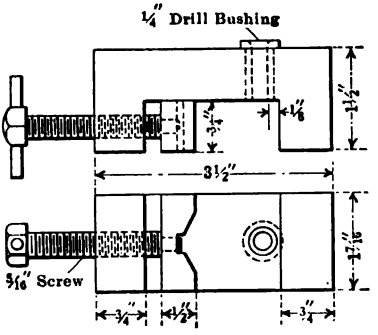


FIG. 253. THE DRILL JIG.

OTHER METHODS OF DRIVING WORK[1]

In driving work on grinders there should be plenty of carriers in pairs, a good supply of driving studs of various lengths, and a supply of centers varying in diameter. The time ordinarily required to put on a carrier is saved if a projection on the work offers opportunity for driving as in Fig. 254. This

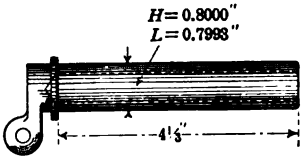


FIG. 254. PIN WITH PROJECTION THAT SERVES IN DRIVING.

example also shows the necessity of centers of different sizes. These metal pins were drilled to lighten them, and the hole forms a center for the grinding operation. The ordinary center for small work (practically a half-center) is not suitable for such a job, as it would wear the hole badly at *A*.

When special strips to drive the work are arranged, the fastening device

[1] W. George.

should be made rapid in action. The ordinary clips, however, can be adapted to suit a variety of work, and are much more convenient and rapid in handling if light spiral springs are inserted to keep the clips open. Figure 255 shows a small bevel gear solid with the spindle; Fig. 256 shows a pair of clips arranged to drive this gear while the spindle is being ground. Two pairs of ordinary clips

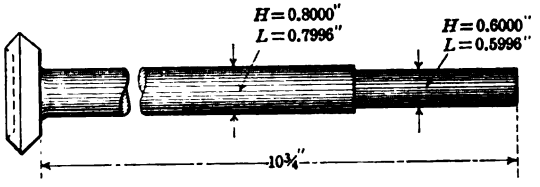


FIG. 255. BEVEL GEAR SOLID WITH SPINDLE.

were bored to fit the bevel tops of the gears, and, on one side, the clips were bored nearly to the largest diameter (*A*, Fig. 256), small springs keeping the clips apart during the change.

The clips were easily slipped on the work and one turn of the screw was enough to grip the work. As the grinder wheel came close to the gear, it was

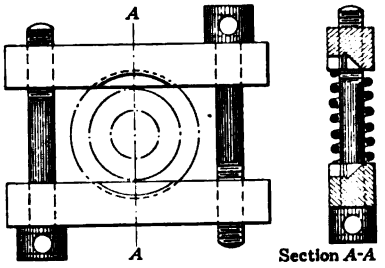


FIG. 256. CHIPS USED IN DRIVING GEAR.

essential that the clips should be straight and that the inside shape of the clip assured this. This is illustrated by the section *A A* through the clip, Fig. 256.

EXPANDING DEVICE FOR GRINDING BUSHINGS

In Fig. 257 is shown a fixture for grinding bushings which is being used very successfully.

Having large lots of small bushings with shoulders at which the wheel must stop, considerable trouble was experienced in grinding them on an arbor as no two of them would stop at the same place on the arbor owing to a slight variation in the size of the holes, and, therefore, the stops of the grinder had to be reset for nearly every one.

In the sketch, *A* is a casting which is bored out and fitted with the bushings *B* and *C*. The spindle *D* is driven by shaft *E* and its pulley, and is made to slide back and forth in bushing *B* by means of the lever *D F*. Part *G* which holds the work is a split bushing ground to fit the taper on the spindle *D*.

When the lever is thrown to the right the taper end of *D* is drawn out to split bushing *G* which then contracts, and when the work is placed upon the bushing and the lever is thrown to the left, the work which is firmly held by the expansion of the bushing will run almost perfectly true with the hole, as *D* and *G* are ground together and the outside of the bushing is ground on the fixture.

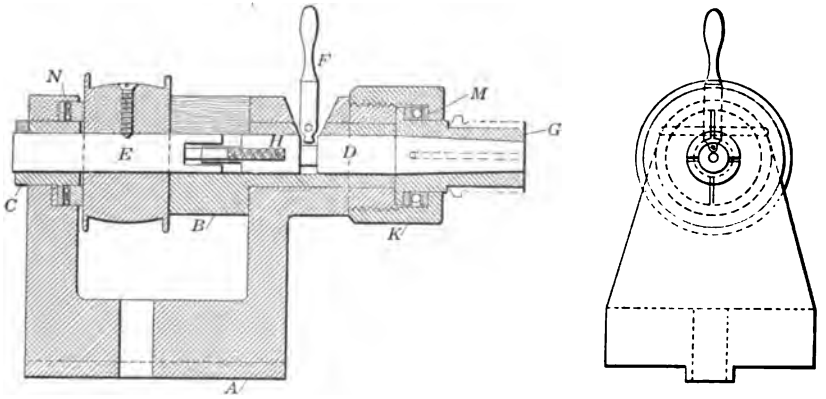


FIG. 257. EXPANDING DEVICE FOR GRINDING BUSHINGS.

The spindle *D* is kept from working out of bushing *G* by the spring and pin at *H* which thrust against shaft and pulley *E*. The cap *K* and the ball-bearing arrangement shown at *M* and *N* take the thrust of spring *H*.

The fixture can be used on any grinder and can be used for grinding almost any kind of bushing by making a suitable bushing to take the place of *G*. Bushings are ground on this device in about one-fifth the time required on a regular arbor.

AN ARBOR FOR TAPER GRINDING[1]

In Fig. 258, the side and end views of No. 1 show a cast iron dial for milling machines, which were turned on the turret lathe and hand reamed before grinding. Grinding was desirable, as by this means a good, cheap finish and uniformity of angles and concentricity with the hole could be secured.

An arbor was made like No. 2, to fit closely in the spindle of the swiveling head of the universal grinder. It had three tapered, adjustable blades dovetailed in, two of them a tight fit and one sliding as shown separately in No. 3. The loose blade differs from the remaining two only in that it has an L-shaped projection at the inner or thin end.

[1] A. B. Christman.

In No. 4 is shown an auxiliary arbor used only in setting the machine. In operation this arbor was placed in the spindle of the head and ground and measured until, by swinging the platen in and out measurements showed the machine to be grinding true and straight when it was removed and the arbor in

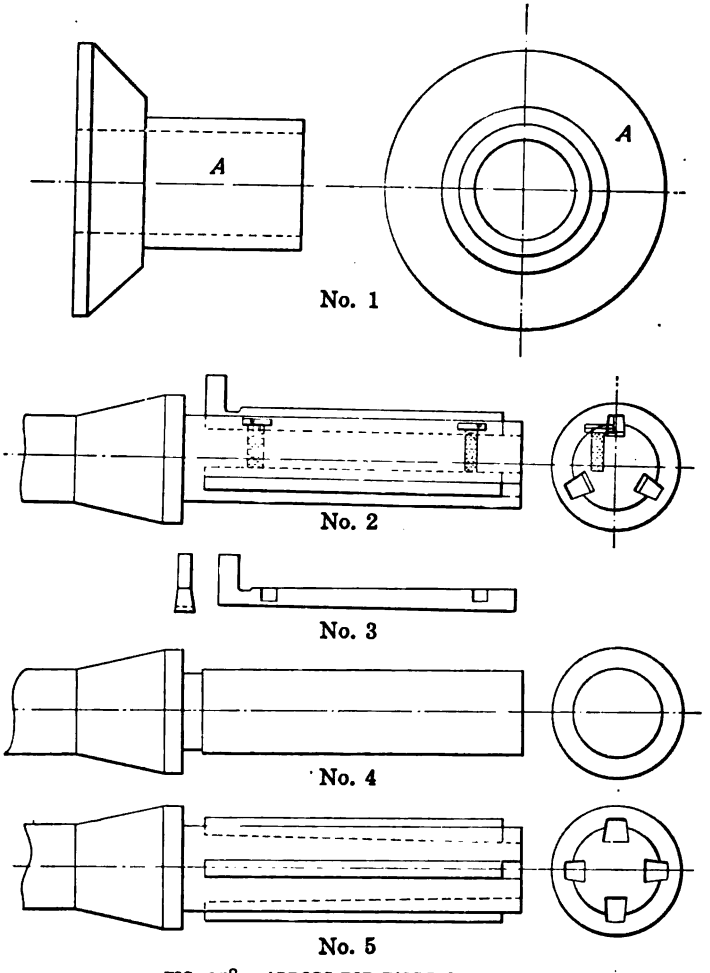


FIG. 258. ARBORS FOR TAPER GRINDING.

No. 2 inserted and ground to size by using one of the dials to be ground, as a ring gage. During this grinding the sliding blade was held in place by the two fillister head screws shown. When the head was swung to the grinding angle these screws were loosened.

The idea was to have the work push the sliding blade before it by means of the projection until by sliding forward it moved outward to engage the hole in the work which would then be held by friction.

An arbor of this kind could be made with all blades a tight driving fit and dispensing with the auxiliary arbor as in No. 5. It should be explained that the blades must be adjustable to allow of setting out for the grinding which is necessary when setting up a job of this kind, as it is impossible to remove and replace such an arbor without disturbing the relation of its circumference to the center about which it revolves.

A MANDREL FOR BRONZE WASHERS

This simple device was designed to hold, for grinding, the bronze washers shown at *X*, Fig. 259. These washers were to be face ground on both sides, and the usual form of expanding chuck was found wholly inadequate.

The arbor is made with a suitable taper to fit the head spindle of a No. 3 Landis Universal grinder, on which the work was to be done.

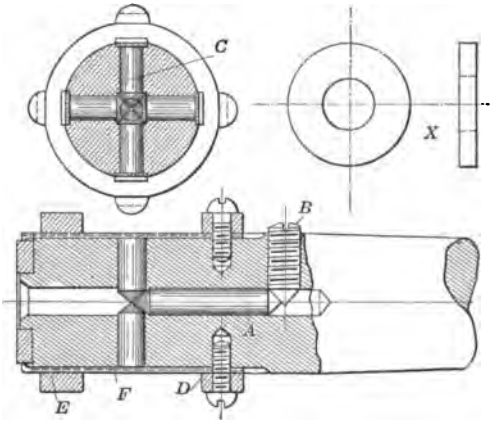


FIG. 259. MANDREL FOR GRINDING BRONZE WASHERS.

The center of the arbor is drilled out and fitted with a pin *A*, having a cone point at each end, the back part being about 100 degrees, included angle, the back end of *A* is fitted to a headless set-screw *B* having a cone point of about 80 degrees. The front end *A* is pointed to 80 degrees to fit the four radial pins *C* having 100 degree points, and it will be readily understood that inward movement of the set-screw *B* expands the four radial pins against four springs *F*. These springs are held in place by two collars *D* and *E*, fastened to the arbor by screws. The collar *E* is provided with four slots, relieved toward the inner face so as to allow the springs free expansion under the pressure of the radial pins.

The springs are provided at their outer ends with lips, the lips being formed to fit the circumference of the washers. The end of the arbor is turned to provide a center for the washers.

The washers come pretty true to size, so only a small movement of the spring jaws is necessary.

RING GRINDING CHUCK[1]

There were a number of rings of hardened steel to be ground on their two faces. They were 4 3/4 in. in diameter outside and 5/16 in. thick when finished. Their inside diameters varied from 2 59/64 to 2 63/64 and after hardening,

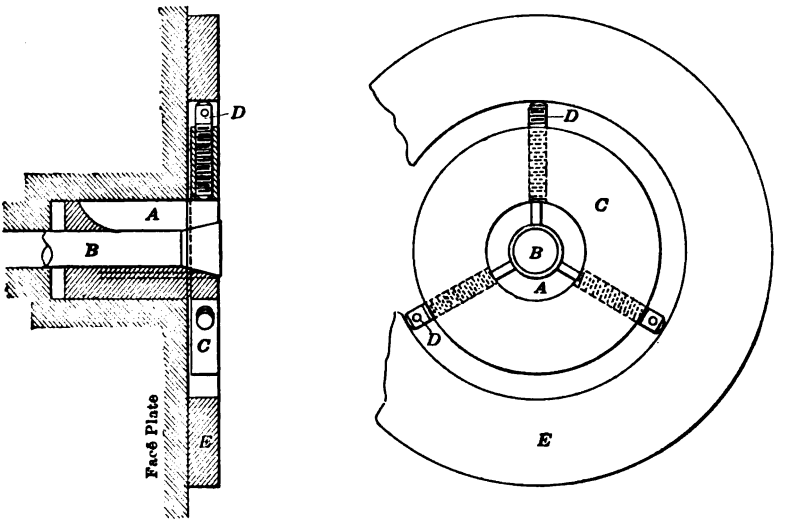


FIG. 260. A RING-GRINDING FIXTURE.

these diameters were out of round. It was deemed unnecessary to grind the diameters, but the maximum variation from parallel permissible for the two sides was 0.001 in.

Most mechanics would know that it would be a hard task to grind the two sides of a ring parallel in a chuck, but this method was tried to see what could be done after the faces of the jaws on the chuck were first ground up. A half day was spent getting two rings ground to within 0.0025 in. of parallel. Then a small spider was made, as shown in Fig. 260, which would fit on the "draw-in" chuck in the grinder face-plate. This chuck consists of a 3-segment spring *A*' the outer end of which is parallel and moves in a 1-in. bore in the face-plate. A draw bolt *B* with conical head expands the spring against spider *C* and draws into the face-plate.

By 3/16 set-screws *D* the spider could be tightened in a ring regardless of the exact size or condition of bore; both could be put on the "draw-in" chuck and pulled up to the face-plate in half a minute. It was not necessary that the ring be exactly central with the spider, but it was arranged for the ring to

[1] R. H. Wadsworth.

pull up against the face-plate before the spider did. Thus the rings E were ground easily and within 0.00025 in. in about 20 minutes each.

EXPANSION CHUCK FOR THE BUFFING MACHINE

The chuck shown by Fig. 261 enabled the operatoıs to hold the work perfectly and to increase the output to a great extent.

The depth of A, the shell, is small in relation to its diameter.

The central expander post B has no end motion, the angle on the expander end being made fairly steep, so that the expanding sleeve C, which is a sliding fit on B, will release itself as soon as unlocked.

The lever D turns the ring C with the post B, which is an extension of the machine spindle proper.

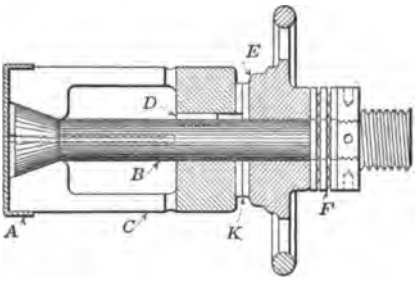


FIG. 261. AN EXPANSION CHUCK.

The locking ring E is the principal feature of the chuck. This ring, with a hand wheel attached, or made integral, as preferred, is made with two cam pieces K directly opposite each other. The locking ring is a running fit on the expander B. The ball thrust bearing F takes the thrust.

The operation of the chuck is simplicity itself. As the buffing spindle revolves, the operator grasps the handwheel on the locking ring E for an instant; this either releases or engages the cams K with the expanding sleeve C, causing it either to contract or expand, as required. In making different chucks for various sizes of work, it is necessary to make only one new piece, namely, the expanding sleeve C. After its first installation the cost of maintenance is very little.

A DRAW-IN CHUCK FOR THE GRINDER[1]

An order came through the shop recently, to make 60 round combination punches and 60 dies for our large gang presses, each press being equipped with 15 dies for punching and forming light metal shells, etc.

The blanking and drawing punch was a simple bushing 3 3/4 in. long.

1 H. T. Stokes.

1 7/16 diameter outside, and 1 1/16 diameter inside, the die being 2 in. long, 1 15/16 outside diameter and 1.439 inside. Both punches and dies had to be hardened and ground all over; also they must be interchangeable in all dimensions within 0.005.

As the shop had no special equipment for this class of work it was necessary to think up a way to get them out. Time was of extreme importance, also the cost had to be kept down as low as possible.

The details in Fig. 262 show how it was done. Patterns and castings were

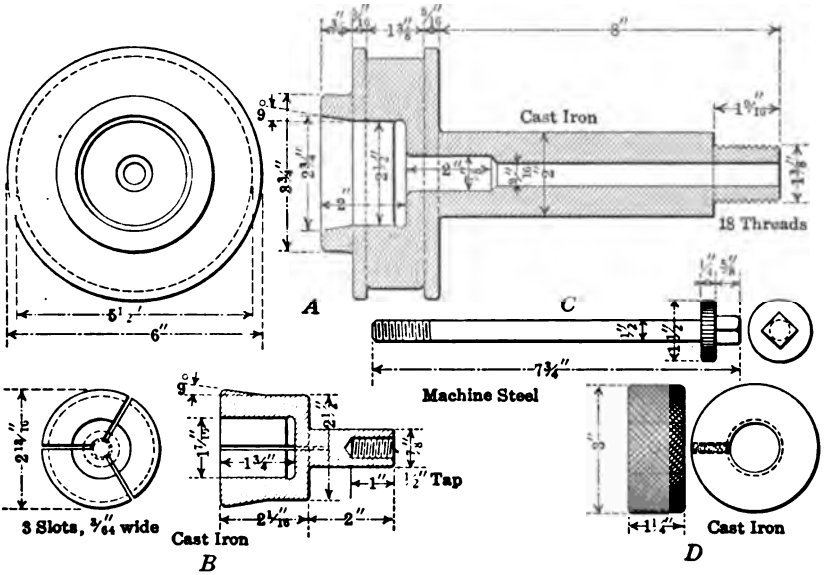


FIG. 262. A DRAW-IN CHUCK ATTACHMENT FOR THE GRINDER.

procured for the parts *A* and *B* of a simple draw-in chuck fixture designed to fit the head of the Bath universal grinder.

Part *A* was machined all over, a few thousandths being left on the inside and on the angle, which was afterward finished in place on the grinder with the internal grinding fixture. This being carefully done gave a good true job.

The chucks like *B* were also machined all over, with stock left inside for finishing by grinding. The slots being milled, etc., 3/64-in. strips of metal were slipped in the front of the slots, then the chuck was placed in the fixture and drawn home with the draw in bolt *C*. The chucks were then ground out true and to size.

In the meantime the punches and dies had been roughed out, hardened and drawn in the oil tempering bath, then rough ground all over to remove strains, and finished in the fixture mentioned. The job was finished on time, with the necessary accuarcy and showing a considerable saving of time above that expected.

The fixture cost little to make and saved its cost on this job alone. Chucks of various dimensions to suit work within the capacity of the fixture can be made up cheaply and added to the equipment of the machine, greatly adding to its usefulness on small work wanted in a hurry. A great number of uses will suggest themselves to any good mechanic in this connection and much small round work now finished in the lathe can be done on the grinder, showing a gain both in speed and quality.

GRINDING QUILL FOR SCREW MACHINE CHUCKS

A convenient device for holding screw-machine collets while grinding out the hole to size is shown in Fig. 263. This particular tool is adapted to receive a Brown & Sharpe No. oc automatic screw-machine collet after it is hardened, and hold it during the grinding operation in precisely the same manner in which

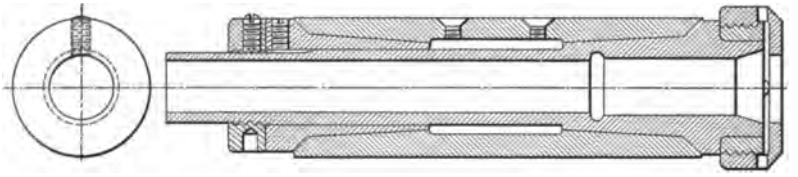


FIG. 263. GRINDING QUILL FOR SCREW-MACHINE CHUCK.

it will later be held in the screw machine when in operation. The quill in which the spindle is carried is slipped into a regular quill rest on the bench lathe or grinder, and the collet to be ground out is readily inserted and as easily removed when the grinding or lapping operation is completed.

All parts, including quill, spindle, rear bearing, cone, cap and adjusting nut are of steel hardened, ground and lapped.

RING CHUCK FOR HOLDING SQUARE PIECES

The chuck in Fig. 264 was designed for holding some small square trunnion blocks on the magnetic chuck of the surface grinder, the required operation being to grind off the ends of the blocks at exactly right angles to the sides.

The outer ring *A*, in which the set-screws are placed which hold the pieces, is fastened to the inner piece as shown with fillister head screws and distance pieces *X X X*.

The inner notched part *B* holds the pieces square with the grinding face. The fixture is filled with the pieces and placed on the revolving table of the grinder and 15 pieces are ground at each setting.

All the parts should be made of machine steel. This little device will be found very useful in many ways.

A GRINDER HEAD

The grinder head illustrated in Fig. 265 was designed to be dust-proof, and is giving good satisfaction. The body and lock nut are recessed to receive

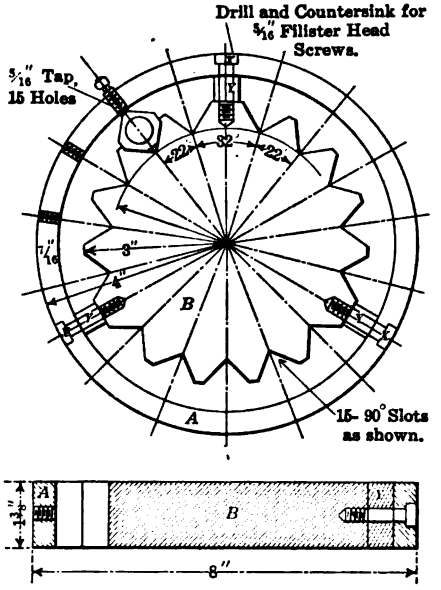


FIG. 264. FIXTURE FOR HOLDING SQUARE PIECES.

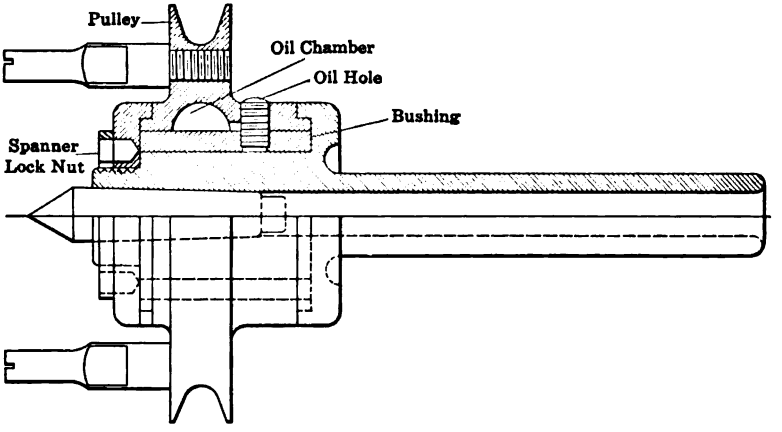


FIG. 265. A DEAD CENTER GRINDER HEAD.

the bushing and pulley. Holes are drilled on a tangent through the bronze bushing in such a way that the oil is forced out of the oil chamber in the pulley

to the journal bearing. The body of the head is stationary, giving the dead center.

The head is simple, compact, self-oiling, dust-proof and has a large bearing surface. The body and retaining collar are of machinery steel, lock nut and drivers of tool steel, pulley of cast iron and the bushing of hard bronze.

CHAPTER XVII

MISCELLANEOUS ATTACHMENTS AND METHODS

The various devices and methods in this chapter, should prove helpful to the reader, as suggesting ways and means for handling some of the unusual jobs that come along from time to time.

GRINDING SPHERICAL END GAGES

Several years ago, C. W. Wright designed the fixture shown in Fig. 266 for grinding spherical end gages. The body *A* of this fixture is of soft steel, with large centers; it is turned down near the middle and at one end to 2 in. diameter, the other end being turned to 3/4 in. to receive the driving pinion *B* which runs

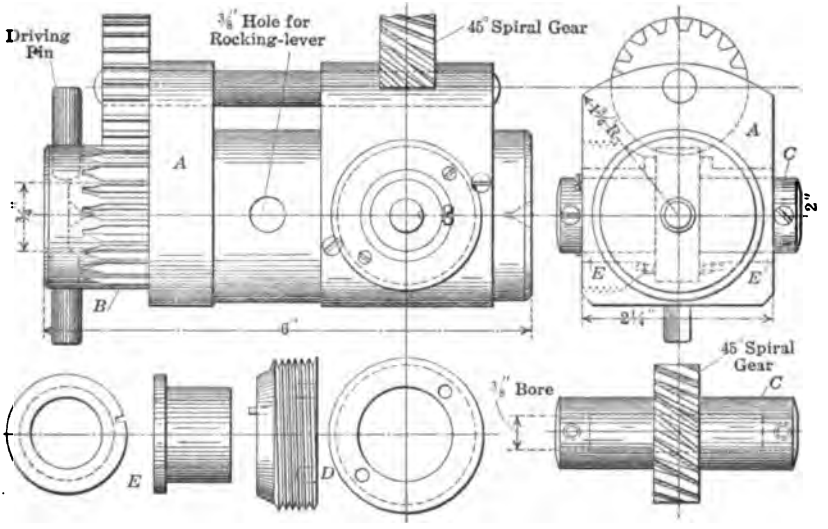


FIG. 266. ATTACHMENT FOR GRINDING SPHERICAL END GAGES.

freely on the stem thus formed. The body is bored from the side square through the center to receive the chuck *C*, and is threaded for the ring *D*. The two bushings *E*, of tool steel, hardened and ground all over, are fitted, one in *D* and one directly in the body to form bearings for the chuck. The chuck with its spiral gear is made in one piece, of tool steel; it is hardened, and gound to a close running fit to the bushings which were lapped out for the chuck after being

put in place. One of the set-screws in the chuck was made with a flat end, and one with a 60-degree point to enter a countersunk hole in the side of the gage to locate it in the right position in the chuck. The hole in the body is for the insertion of a piece of 3/8-in. rod which is used to oscillate the fixture in front of the wheel.

This attachment is mounted on the centers of the grinding lathe with the drivers in the face-plate engaging the pins in the driving gear *B*. The gage is put in the chuck and located and held by the set-screws, and the 3/8-in. rods inserted in the body to prevent the device from turning around on the centers as well as to oscillate it. The machine is then started (chuck *C* driven through

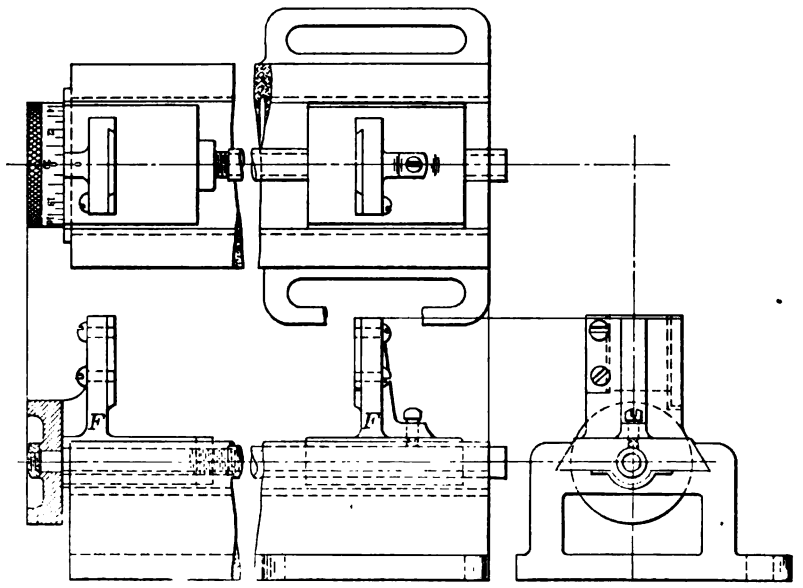


FIG. 267. LAPPING RIG FOR GAGES.

the spur and spiral gears running at from 1000 to 1200 turns per minute) and the grinding wheel brought to position to grind the end of the gage as it is oscillated before it; then without changing the position of the wheel the attachment is turned over to bring the other end of the gage to the wheel, the rocking rod being slid through the body, so that the other end may be grasped. By thus turning the gage over without moving the wheel, both ends are, of course, given the same radius.

When the fixture was first put into use it was found that all the gages were a little inclined to be flat or low in the center, this flatness being more perceptible in short gages than in long ones. In order to overcome this trouble, many things were tried, and finally it was decided that the only way to cure the defect would be by lapping the gage after it was ground. As it was thought both ends

could be lapped at once, a rig was made like Fig. 267 for the purpose. The two jaws *F* are fitted to slide in the body and are free to move in either direction, but their distance apart is limited by the screw *G*. Pieces *F* are faced with soft brass, as this will hold emery better than cast iron will.

This rig is to be fastened on the grinding machine in place of the emery wheel, and in such a position that when the gage grinder is on centers, with a gage in place, the two lapping faces will come at the ends of the gage. In operation, the gage is oscillated in the same manner as when grinding the ends, flour emery and oil being used on the laps. By means of this lapping rig it was found easy to get the ends to the desired shape.

A 3/8-in. drill rod was used to make the gages, this being cut off 1/16-in. longer than finish size. The time following was taken from a lot of 25 or 30 that were made at one time, before the first 100 gages were completed: Cutting off, marking, laying out and drilling center hole in side and polishing, 22 minutes each; grinding ends to within about 0.0015 or 0.002 in. of size, 22 minutes each; lapping to size and testing, 73 minutes each, making a total of 1 hour and 57 minutes per gage, and very likely this time can be reduced considerably. It was found that long gages were easier to make than short ones, as the tendency to flatten was less. When making the second gage of a given size, in order to bring both to the same temperature for measuring or testing they were cooled off together in water, and measured immediately. This was found to be a very satisfactory method.

ANOTHER DEVICE FOR GRINDING SPHERICAL END GAGES

Figure 268 shows another arrangement for grinding the ends of end-measuring rods spherical. It was made to clamp on the slide of a cutter-grinding machine. The end-measuring gage to be ground is held in the holder *A* by the nurled-head screw shown; this holder is free to revolve on the screws *B* and *C* in the yoke *D*, which is also free to revolve in the body *E* so that when the end of the rod to be ground is brought into contact with the emery wheel it can be moved in any direction and made to pass over any point in a sphere, thus forming a spherical end, the radius of which is the distance from the center of the holder *A* to the end of the rod. This radius can, of course, be anything within the capacity of the device. No. 2 shows a holder for using end-measuring rods as a limit gage, and No. 3 shows another convenient form of holder.

USING A MILLER TO GRIND CAMS

Recently some cams were made which required particular accuracy, and as they had to be hardened it was decided to grind them on the face that the roll bore against on the rise only, as the return was not important.

The cam blanks were about 3 in. in diameter and 6 in. long, and the cams proper about 3/4 deep and 1 in. wide at the top, the sides being at an angle of 14 1/2 degrees. The lead was from 1 1/2 to 3 in. on the different cams. After

hardening, the cams were swung on the centers of the spiral head of a milling machine which was geared to the correct lead.

The arm of a Brown & Sharpe compound vertical milling attachment was clamped to the overhanging arm of the machine and to this was bolted an internal grinding fixture, belted to a countershaft on the floor at the side of the machine. This was speeded to 12,000 r. p. m. The arm was placed so as to

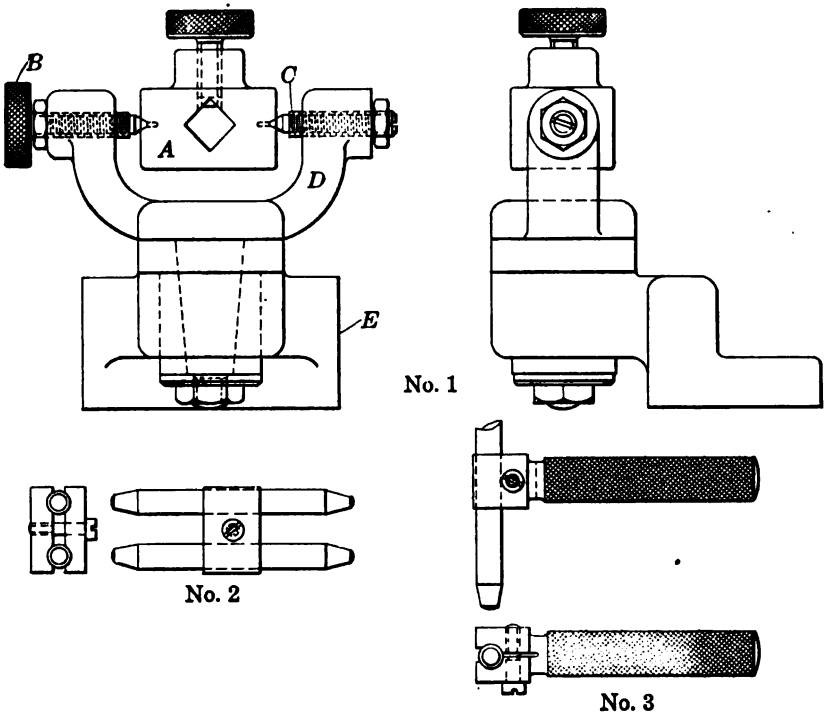


FIG. 268. ANOTHER DEVICE FOR GRINDING SPHERICAL END GAGES.

bring the center of the wheel on a line with the center of the head. The table was swung at an angle of 14 1/2 degrees to match the sides, and the wheel trued small enough to go to the bottom of groove without touching the other side.

The required feed was obtained by turning the spiral head crank by hand and the depth of cut by moving the cross-feed of the machine.

In this way was obtained a very satisfactory job with a smooth finish. Figure 269 shows how it was done.

A CAM GRINDING FIXTURE

This fixture is shown clearly in Fig. 270. *A* is the base, with the cam-stop *B* and the fulcrum lugs *C* cast on. *D* is the spindle carrier, which is mounted on rock shaft *E* and carries the spindle *F* at the top end. The spindle is held in

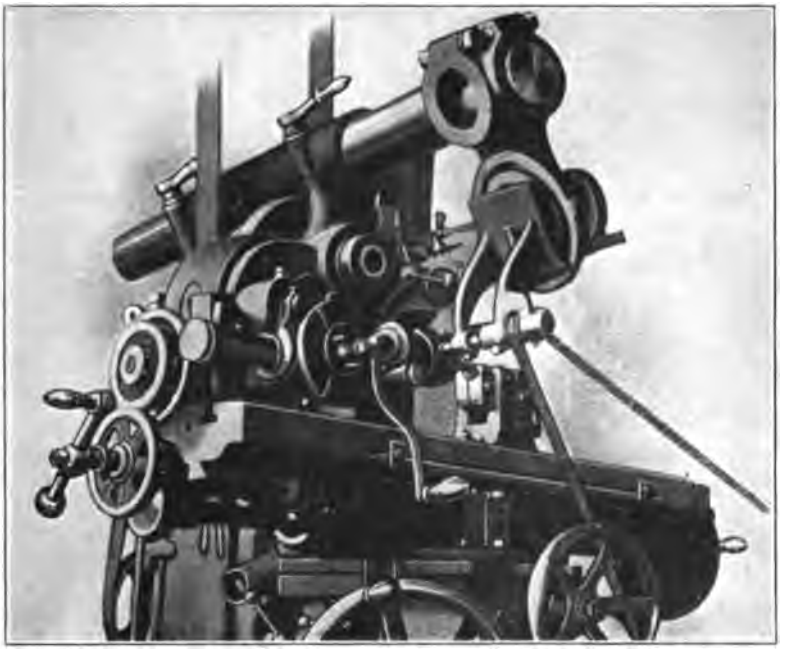
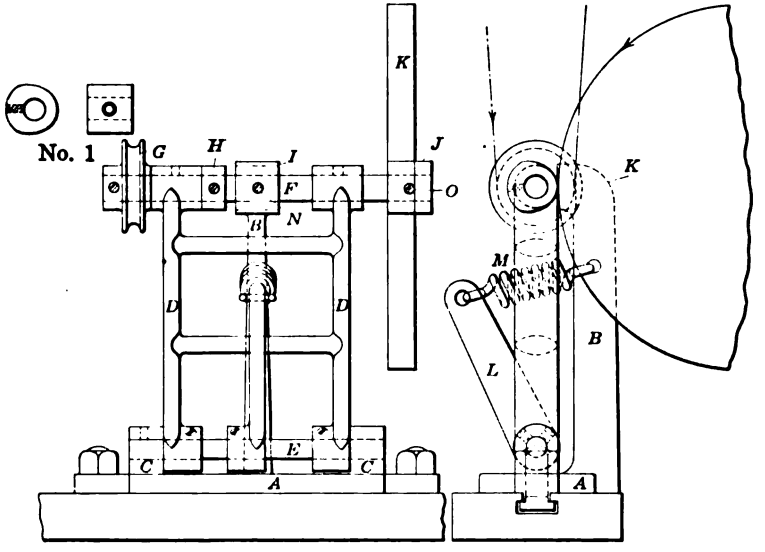


FIG. 269. GRINDING CAMS ON THE MILLER.



No. 2

FIG. 270. CAM-GRINDING FIXTURE.

position by the driving pulley *G* and the collar *H*. At *I* is the master cam, and at *J* is the cam to be ground. *K* is the emery wheel. The lever *L*, which is secured by a headless screw to shaft *E* (to which shaft the lower end of the spindle carrier *D* is also fastened by a screw), is drawn forward by the spring *M* until the cam *I* comes in contact with the cam-stop *B*.

The cams are rough milled on the cam cutter, no particular care being taken as to their exactness, whereas, heretofore, every care was taken without avail; they are held in position by screws which fit in a spot on the cam-cutter shaft. These screws it is necessary to have in the same position in each cam. The cams are then case-hardened and ready to be ground. On the shaft *F* are drilled two spots *N* and *O* in perfect alinement. The screw at *N* locates the model cam *I*, while that at *O* secures one of the rough-milled cams to be ground.

As the pulley *G* rotates, the spindle-carrier *D* takes a rocking motion, as cam *I* is held against the stop *B* by the spring *M* and lever *L*. The cam *J* necessarily takes the same motion against the emery wheel *K*, and is ground to a facsimile with a perfect surface.

BEVEL GRINDING ATTACHMENT FOR THE PLANER

An angle grinding fixture is shown in Fig. 271 as used in connection with an ordinary planer, it being mounted on the cross rail thereof.

This fixture was designed to grind the bevel on long lengths of stock of cross-section as shown in drawing, and consists of a base *A*, upon which is mounted the bed plate *B*. This in turn carries the slide *C*, which accommodates the shaft *D* and the emery wheel *E*. The base *A* is provided with slotted ears *a a*, by means of which it is bolted to cross-rail carriage of planer.

Bed plate *B* is seated and turns in base *A* upon the conical seat *b b*, and is held in place by the bolt *c* which fits loosely in casting *B*. The bolts *d d* work through the slots *e e* and when loosened allow the bed plate to be turned either way from center, up to 45 degrees, and clamped in place at any angle as indicated by the pointer *f*. The projecting arms *g g*, of the slide *C*, carry the shaft *D* on which is mounted the pulley *F* and emery wheel *E*, as shown. Shaft *D* runs in bronze bushings *G G*, and is adjusted for end-shake by means of the spring checknut *H*. A similar checknut is used on the opposite end of shaft, to tighten the clamping members *h h* upon the wheel *E*.

Transverse movement of the slide *C* is effected by means of the screw *I* working in nut *J*, which is screwed to the slide. The housing *K* is screwed to the bed plate *B* by the screws *i i*, and serves the double purpose of a support for end of screw and preventing lateral motion of the latter. Screw *I* is turned by the handwheel *L*, keyed by the feather pin, as shown, and held in place by checknut *J*. End of housing *K* is graduated to 25ths, in the full circle, which, with the 40-pitch screw *I*, gives a feed of 1/1000 in. for each graduation.

In operation, the bar to be ground is clamped upon the planer table and

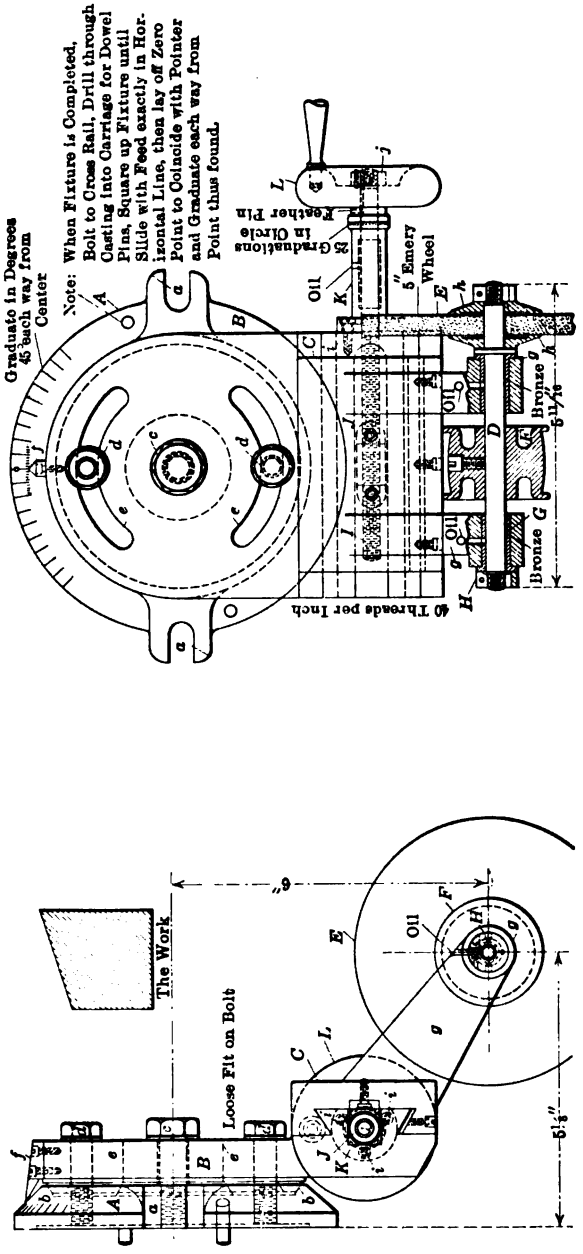


FIG. 271. BEVEL-GRINDING ATTACHMENT FOR PLANER.

fixture is mounted upon cross rail. For grinding stock that is square in cross-section, the pointer is set at zero and either the cross feed of planer or that of fixture may be used; but when grinding down a bevel at any certain angle the feed on the fixture alone is, of course, used.

GRINDING ON THE SHAPER

The E. M. Erb Manufacturing Company, Jersey City, N. J., has two neat grinding fixtures for use on their shaper, both of which are shown in Fig. 272.

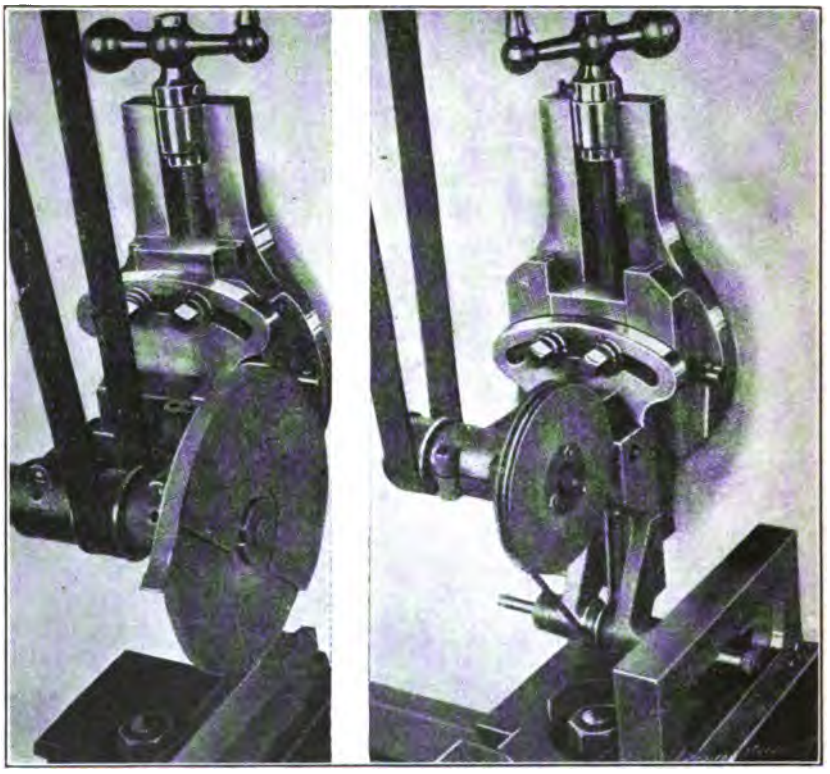


FIG. 272. GRINDING ON A SHAPER.

The fixtures need little explanation except that the main bearings are set on a cast-iron block, which is placed in the clapper box and held in by a large screw, a hole being drilled and tapped in the back of the clapper box for the purpose.

The ram and its bearings are covered with canvas to keep out the emery dust thrown off while grinding.

The grinder is driven from an extra countershaft, shown in Fig. 273, the idler

set into a piece of heavy 4×4 oak, keeping the belt taut during the stroke of the ram.

Punches, dies and all sorts of grinding jobs common to the small shop, are quickly and satisfactorily done with one or the other of these fixtures.

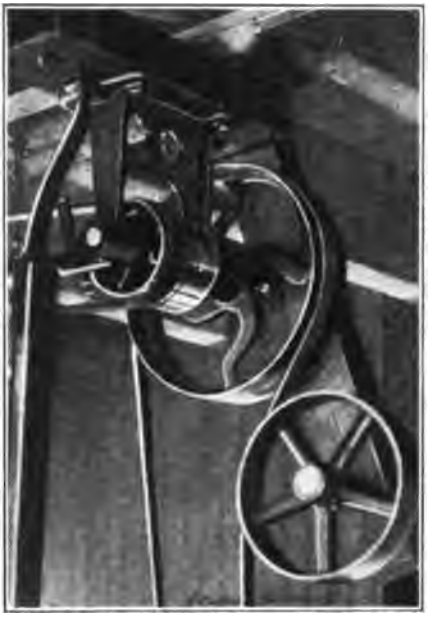


FIG. 273. COUNTERSHAFT AND IDLER USED WITH SHAPER GRINDING FIXTURES.

A GRINDING ATTACHMENT FOR A SMALL WHEEL

The arrangement in Fig. 274 is an attachment to use on a small emery wheel. The attachment is composed mainly of two parts, which are *B* and *C*. *B* is a flat table with three T-slots on top and one T-slot and one V in front. This table is connected to *C* by the bolt shown at *D*, which is a nice fit, so as to have no looseness whatever between the parts. *C* is the part that fits on rod *E*. It is also supported on rod *F* and is split to clamp fast to rod *E*. The end piece *G* is for adjustment, so that the plate *B* can be placed in any desired position and held there by the thumb nut *H*. The plate *B* is cored out as much as possible to make it lighter to handle. The parts *A* and *B* are the adjusting collars and clamps. The collars *A* are placed one on each end of rod *E* with the screws for adjusting up against the rod bearings, and the clamps *B* are for holding the work against the table. The V at *A* is for holding pin gages, and can also be used for other work. The attachment can be used for quite a number of purposes. For instance, it may be used for grinding off the ends of pieces for

dies that are too large for the surface grinder. The emery wheel used is recessed out so that it can travel across the part to be ground. The tool is especially useful in the grinding of snap gages.

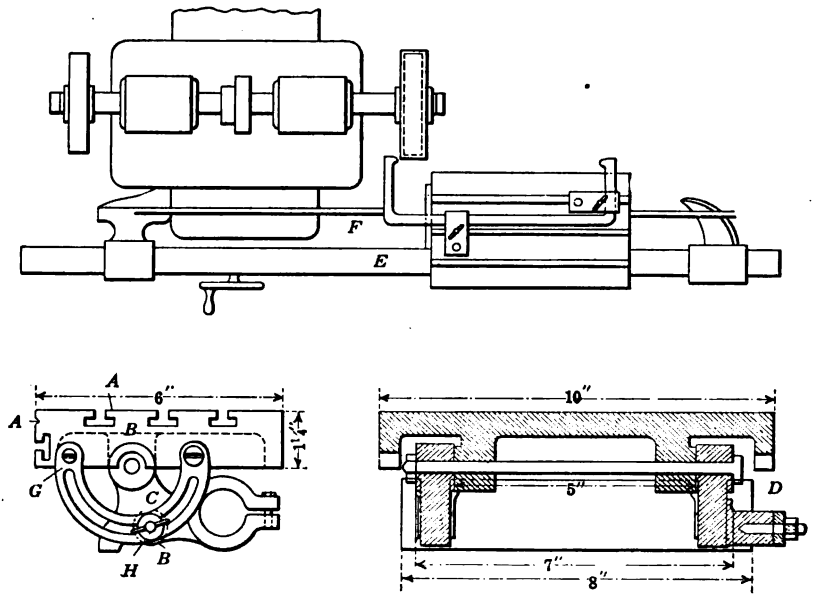


FIG. 274. A GRINDING ATTACHMENT FOR SMALL WHEELS.

A TIME SAVING MIRROR AND A MAGNETIC WORK HOLDER

Figure 275 shows a mirror in working order. *A* is a mirror held in position, about 2 in. back from the face of the emery wheel and inclined a few degrees from the perpendicular, the bottom edge of the glass being about 2 in. below the level of the machine table *B*. It is fixed to a piece of flat, mild steel fastened to the machine frame, as shown at *C*, and bent so as to clear the emery wheel.

D is a magnetic work holder (shown more clearly in Fig. 276) and consists of a brass casting having four 1-in. holes into which are inserted two hardened-steel permanent magnets *E*. These are ground off level with the face *F* (which is machined) and forms a flat face for the work to rest against. The magnets are held in place by four brass screws *G* (two of which only are shown), the other two being inserted from the under side.

H J K are mild-steel thrust plates; these prevent the work from falling down, or moving sideways when in contact with the emery wheel. The magnetic holder is provided with a loose tongue on the under side for positioning it square on the grinder table, the tongue, of course, being removed when it is required to use the holder on the ordinary disk grinder when the faces *L* form the necessary squaring stops.

To operate, the work is placed on the face of the magnetic holder and fed across the face of the emery wheel; it is then brought opposite the mirror *A*; the operator without changing his position from the hand wheels can see at a

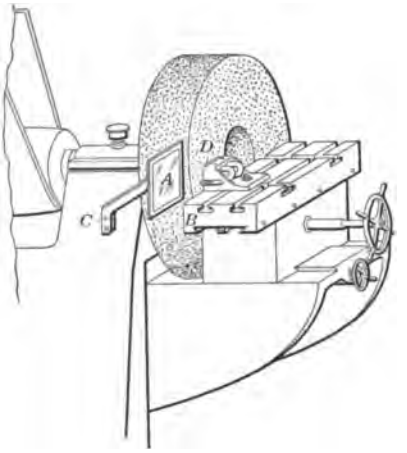


FIG. 275. THE MERRON IN USE.

glance by the reflection in the mirror, whether or not the work is done. Steel stampings, castings, and drop forgings are treated in this manner, and in most cases, since the mirror has been adopted, a saving of 50 per cent. in time taken has resulted.

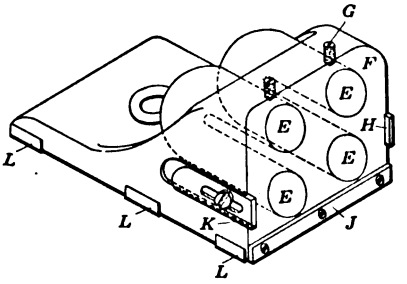


FIG. 276. MAGNETIC WORK HOLDER.

ATTACHMENT FOR DISK GRINDER

The illustration, Fig. 277, shows a small attachment used with great success on disk grinders. It can also be used with advantage on any grinding machine which has a table for it to rest upon. The construction of it is as follows: The body *A* is of gray iron, and carries a steel spindle *B*, bored at its front end to take a standard taper plug *C*. The small hole *D* through the spindle is for convenience in knocking the plug out. In the sketch a small drill chuck used for

holding small articles, such as screws, pins, studs, etc., is shown on the taper plug. To the other end of the spindle is keyed a small steel pinion *E*, having 24 teeth, 12 pitch. This pinion is driven by a gear *F* with 48 teeth, which is carried by a stud supported by an arm *H* extending out from the body. A handle *G* is fixed in this gear for rotating it by hand. The pinion is held on the spindle by a lock-nut *I*. The body slides along the upper base *J*, and *J* rotates on the lower base *K*. Thus a combination of a horizontal sliding movement can be obtained together with a circular movement.

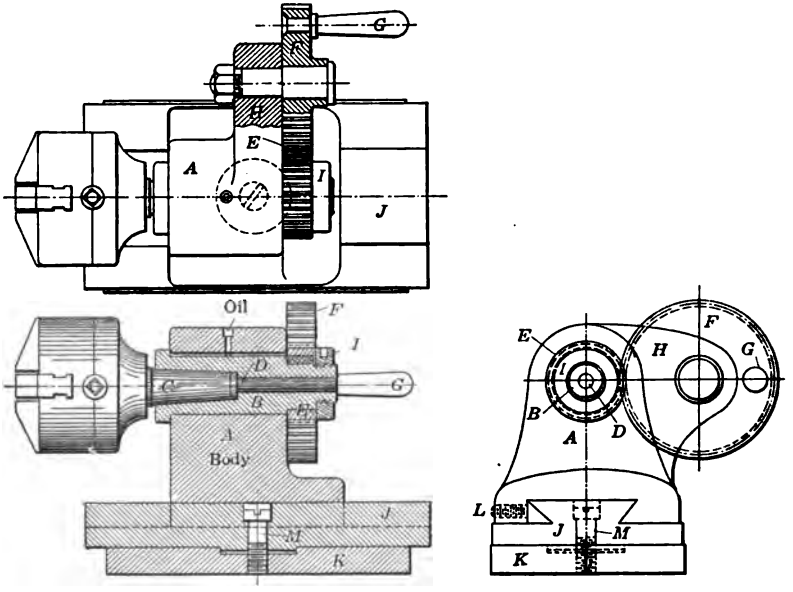


FIG. 277. THE GRINDER ATTACHMENT.

For spherical grinding the body *A* can be locked at any position along *J* by means of the set-screw *L*, according to the radius of rotation required. The work is held in the chuck, and the combination of rotating the spindle in one direction together with the body truning round in the recess in the second base gives a spherical movement. For parallel grinding *J* can be locked by means of the screw *M* and the body *A* slides along the base. By locking it at an angle, taper work can be ground.

FIXTURE FOR GRINDING A BALL END

In repairing a machine it was found necessary to make a hard-steel ball 1 in. diameter at the end of a 5/8-in. threaded shank. The line engraving, Fig. 278, shows how the small Cincinnati tool and cutter grinder was rigged to finish the ball. The attachment is cheap to make, and enabled the operator to grind the

ball to within 0.001 in. of spherical; this was as good as the job required. The ball was rotated and the fixture was swung around the pivot pin. The center of the pivot pin was exactly perpendicular with the center of the ball.

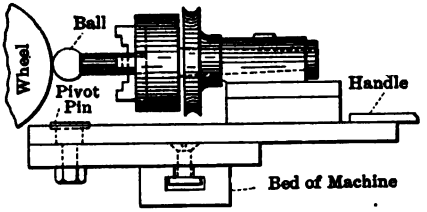


FIG. 278. GRINDING A BALL ON THE END OF A SHAFT.

DOUBLE GRINDING OPERATION

A neat grinding fixture was recently devised by the Dayton Machine and Tool Company to grind the beveled edges of small friction-driving wheels for toy locomotives. These wheels are of cast iron, about 2 in. in diameter, and have a 45-degree bevel on each side which works in a frictional arrangement so that they must be true and of correct size.

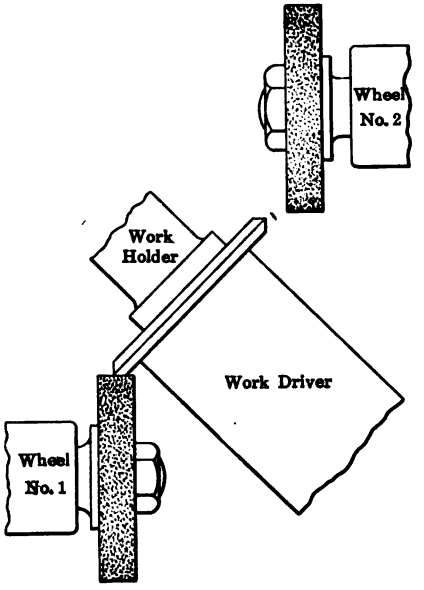


FIG. 279. DEVICE FOR GRINDING A BEVEL ON SMALL WHEELS.

Figure 279 shows how this was done with very little trouble, the work being held and revolved at an angle of 45 degrees from the grinding wheels. It is only necessary to stop the work-driving spindle, take off the finished wheel and put on

a new one, snap the back stop or holder into place and start up again. Then the head carrying the work is moved past one wheel and then the other, grinding both sides in short order and making a very good job of it. The setting of the two grinding wheels determines the diameter of the driving wheels as they are ground to a sharp corner.

A LINK GRINDER

A novel form of a link-grinding machine used in the C. M. & St. P. R. R. shops at West Milwaukee is shown in outline in Fig. 280. It consists of the grinding head carried on the vertical column at the back and a frame consisting

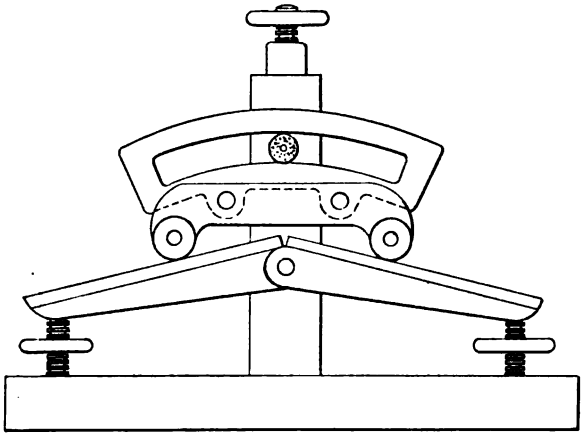


FIG. 280. A LOCOMOTIVE LINK GRINDER.

of two sets of V-tracks hinged in the center and adjustable at the outer end by the screws and hand wheels shown.

The link to be ground is mounted by its hanger holes in the carriage or truck. The tracks or ways are adjusted to the right angles to give the desired radius as it is moved back and forth, one end going up and the other one down as it is pushed back and forth by hand, the combination giving the curve of the radius desired for the link.

For grinding the block there is an attachment which goes on the back of the carriage, holding it by its pin hole and allowing the proper curve to be ground in the same way.

The grinding head is adjusted to secure the proper location of wheel for either internal or external work, automatically tightening the belt at all times, and the whole machine has an air of simplicity and effectiveness.

BORING OUT ABRASIVE WHEELS

The sketch, Fig. 281, shows an outfit used in boring out a grinding wheel hole which was 3/8 in. too small.

A is an Armstrong boring tool, *B* a piece of 3/4-in. cold-rolled steel which at one end is bored and tapped for a 5/16-in. cap screw *D*, which holds the emery-wheel dresser cutters *C*. Running the lathe at high speed, after chucking the grinding wheel, this was used the same as an ordinary boring tool, enlarging the hole 3/8 in. in a very short time.

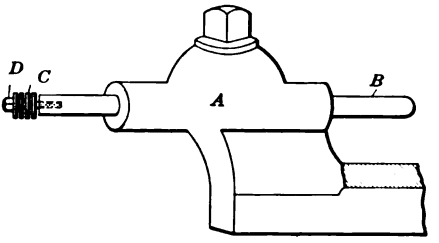


FIG. 281. TOOL FOR BORING OUT ABRASIVE WHEEL.

CUTTING OFF STOCK

One of the newer developments of the grinding machine is for cutting off stock. Tubing, which is particularly difficult to cut off satisfactorily in most machines, can be cut off very evenly and smoothly, as well as rapidly, by the grinding machine equipped with the thin, flexible wheel. A few examples of the work are shown in Fig. 282.

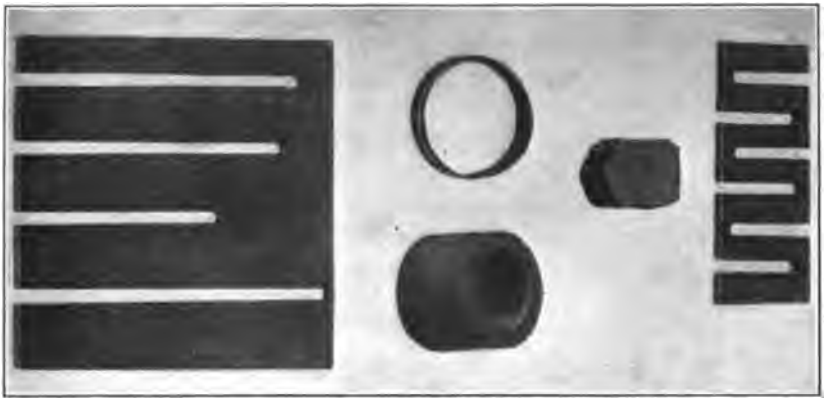


FIG. 282. WORK OF A CUTTING-OFF WHEEL.

These are known as the elastic or shellac wheels, being made in molds with a shellac bond, placed in ovens and put through the same processes of manufacture as the vitrified and silicate wheels. They can be made very thin when necessary and are safe, due to their great elasticity. Wheels as large as 8 in. in diameter can be made only 1/16 in. thick if necessary, and a 12-in. wheel can be made only 1/8 in. thick when desired.

They are specially useful in cutting up high-speed steel as the cutting is done very rapidly and it avoids the waste of stock which too often follows the nicking and breaking of the bar.

Those who are not accustomed to this method can hardly realize the speed with which the work can be done.

In some cases small and hard castings are cut with wheels of this kind instead of being milled. Individual automobile piston rings are cases of this kind.

Wheels of this kind seem to be self truing and no trouble need be taken on that account. They can be run in water or soda mixtures if found desirable.

They are also used for cutting up thin strips of steel, or brass, tubing of all kinds, hard or soft wire and other material which is difficult to hold for cutting by regular tools.

The cutting speed should be about 6000 ft. per minute.

WHEELS FOR CUTTING OFF STOCK

Wheels used for cutting off stock are thin, quite flexible and run at very high speed. One user who has had a wide experience in this line recommends a 3/32-in. thickness, 12-in. diameter corundum wheel, running about 3000 r. p. m., or nearly 2 miles a minute. He suggests grade 5E, number 46/60 for practically all cutting off work.

Such a wheel will cut either high-speed or carbon steel 1/4 in. thick at the rate of 3 in. per minute or a piece 1 in. square in the same time. While it might cut a little faster than this it does not pay to crowd it too much as the wheel must cut its way clear to get the best results.

It is important that the spindle bearings be a good fit as they cause chattering if they are loose, and chattering and crowding have a bad effect on the life of a wheel.

Brass tubing, 1 in. outside and having 1/8-in. walls requires from 10 to 12 seconds; steel bicycle tubing varies from 6 to 10 seconds. Brass and other soft metals can be cut in about half the time of high-speed steel.

1 1/2 in. cold rolled steel	22 to 25 seconds
15/16 in. cold rolled steel	12 to 14 seconds
1/2 in. cold rolled steel	6 to 7 seconds
3/8 in. × 1/2 in. high speed steel	4 seconds
1/2 in. sq. high speed steel	6 seconds
5/16 in. sq. high speed steel	5 seconds

The life of a wheel varies with the work done and the way it is handled, but it is safe to count on making from 1000 to 1500 cuts on 5/6 in. high-speed steel before the wheel is worn out.

Cutting off machines of this kind have a belt capacity of about 6 horsepower as a maximum.

USES OF POWDERED OILSTONE

The advantages of this substance are so little appreciated by mechanics generally that the following data supplied by Frank Metzler should be of considerable value.

The powder is the refuse from the cutting of stones to the desired forms and is to be obtained from the supply houses at 10 cents a pound for the American make, and 20 cents a pound for the French. For economical reasons and in view of the satisfactory results obtained, a trial is recommended particularly where close work is the general practice.

Let us say we have a circular former cutter which through hardening or other causes gave an incorrect size on the finished product. This is very apt to occur when the cutter is fed to cut on the side, necessitating the cutter being set on an angle; part of the cutter, if it be a broad one, will be considerably below center, sufficiently so to produce a wrong diameter. This can best be corrected by the use of oilstone powder and a cast-iron lap, particularly where sharp corners are desired, whereas otherwise it would most likely necessitate a new former. With the most suitable emery wheel one cannot approach the sharp corners and smooth surface obtained by oil.

USE OF OILSTONE ON A CAST-IRON LAP

The method employed is the same as one would use in emery-wheel grinding, in place of the emery wheel a cast-iron lap about 2 in. in diameter being used, running at a speed of about 600 r. p. m. or a surface travel of 314 ft. per minute. The surface travel of the cutter should be approximately the same, just slow enough to prevent the oilstone from flying off the lap. The oilstone is mixed with oil for convenience of applying, besides adhering to the lap better when wet. It is applied to the lap with a small brush, and but a small quantity at a time is required to perform its work. Care must be taken to avoid crowding the lap, otherwise the sharp corner so much desired is lost. An ear trumpet, as is commonly used in light boring, is a great advantage.

FINE FINISH ON CUTTERS

Let us say we have a master former cutter, which we wish to reproduce with accuracy. It is in such cases as this that the great advantage of oilstone comes in; its use leaves on the cutters absolutely no burs, which have been the source of much annoyance to good mechanics and others. We have brought the cutter we are making down to form, and desire to take a finish cut leaving a sharp and true form. Take the cutter, place it on a table rest and sharpen it with oilstone; it gives a perfectly flat and smooth top absolutely free from the slightest bur. A better condition could not be desired. The lap in this instance should be from 4 to 6 in. in diameter.

A FIXTURE FOR OILSTONING THREADING TOOLS

Many shops do not have the patented threading tool, and those that do supply them frequently find the old-style tool in use. In this connection oilstoning with a fixture, as shown in Fig. 283, should be adopted as a matter of economy. The excellent condition in which the oilstone leaves the tool dispenses with the necessity for the man standing at the grindstone calling his

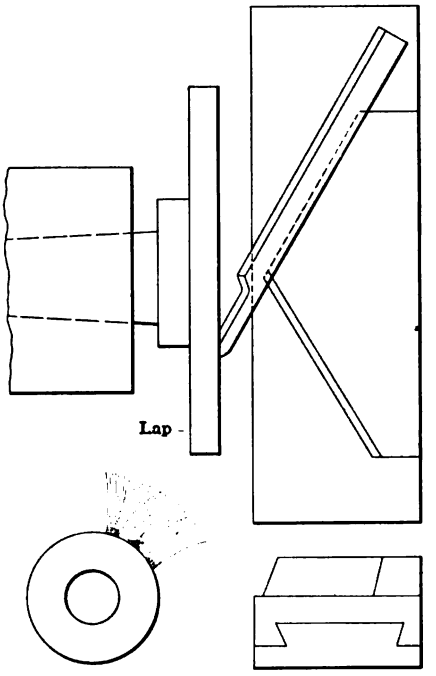


FIG. 283. GRINDING ATTACHMENTS.

reserve genius into play trying to exclude light from between the gage and the tool.

The tool is placed on the fixture, oilstone applied to the cast-iron lap—which should have been roughed with a coarse file, the lines running radially to permit lodgment of the oilstone—and with a gentle pressure of the tool against the lap the slide should be moved back and forth. The result is just what we are after.

USE OF OILSTONE ON BRUSHES

A circular bristle brush is mounted on the lathe, with the use of oilstone will clean hardened work of fire stain and remove small burs from work while

soft, without damage, if a very small quantity is used. It is particularly useful on small ratchet teeth and pinions and work of that nature.

To remove burs on hardened work, a wire brush as in Fig. 283, is more satisfactory. For the convenient handling of oilstone on brushes and felt laps, when used for the purpose of smoothing a rounded surface before polishing with powdered lime, melt a small quantity of paraffin wax, add oilstone powder and stir until it thickens somewhat, keeping it warm meanwhile. Then set it away and allow it to cool. Oilstone in this form will stick to the brushes and felt better than with oil.

CHAPTER XVIII

OILSTONES AND THEIR USES

NATURAL STONES

Some interesting particulars regarding the well-known Arkansas and Washita stones are given by the Pike Manufacturing Company as follows:

Arkansas stones are made from rock quarried in the Ozark mountains of Arkansas, and are prepared for commercial purposes in two grades, hard and soft.

Hard Arkansas is composed of pure silica and its sharpening qualities are due to small, sharp-pointed grains, or crystals, of hexagonal shape, which are much harder than steel and will, therefore, cut away and sharpen steel tools. The extreme fineness of texture makes this stone of necessity, a slow cutter, but in the very density of the crystals of which it is composed, lies its virtue as a sharpener.

Soft Arkansas stone is not quite so fine-grained and hard as the hard Arkansas, but it cuts faster and is better for some kinds of mechanical work. It is especially adapted for sharpening the tools used by wood carvers, file makers, pattern makers, and all workers in hard wood.

Washita stone is also found in the Ozark mountains in Arkansas, and is similar to the Arkansas stone, being composed of nearly pure silica, but is much more porous. It is known as the best natural stone for sharpening carpenters' and general wood workers' tools. This stone is found in various grades, from perfectly crystalized and porous grit to vitreous flint and hard sandstone. The sharpness of the grit depends entirely upon its crystalization, the best oilstones being made from very porous crystals.

In addition to the regular rectangular sections, natural stones are made in such shapes as square, triangular, round, flat, bevel, diamond, oval, pointed, knife edge.

ARTIFICIAL OILSTONES

Artificial oilstones are manufactured in a multitude of shapes and sizes and are adapted for sharpening all kinds of tools. Such stones are made by the Norton Company of alundum and crystolon, the former being known as India oilstones, the latter as crystolon sharpening stones. Similar shapes are manufactured by the American Emery Wheel Works, and the Carborundum Company also makes such stones in great variety.

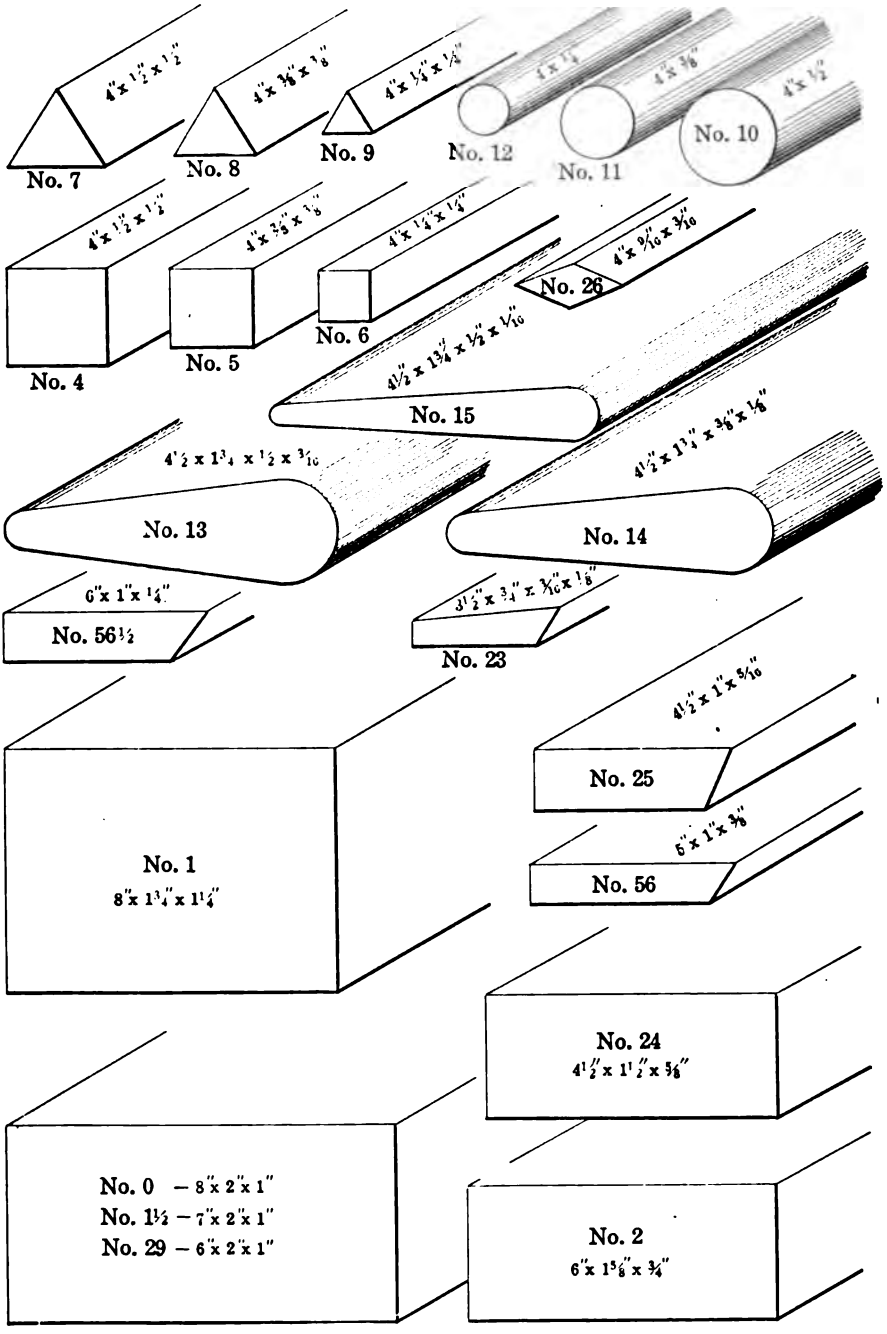


FIG. 284. OILSTONE SHAPES FOR MACHINE SHOP USE.

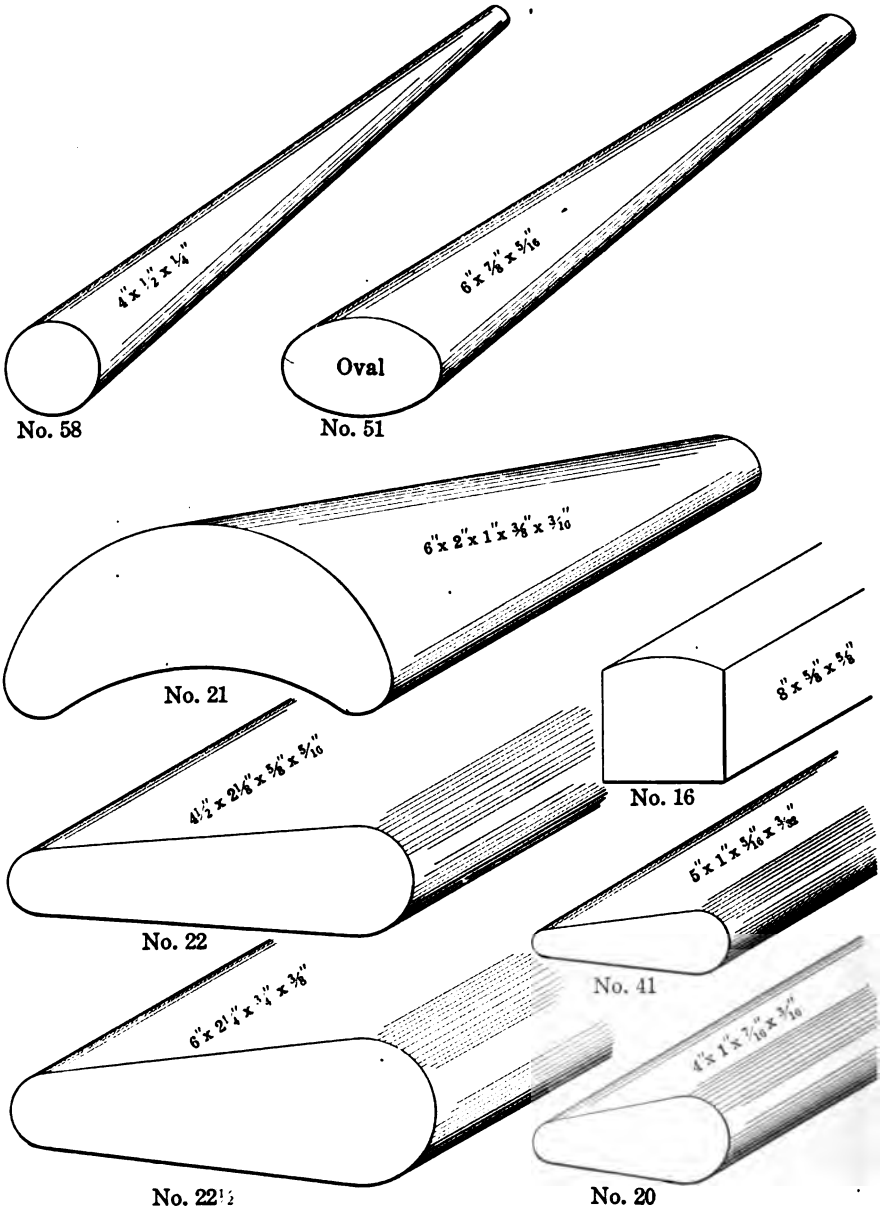


FIG. 285. OILSTONE SHAPES FOR GAUGES, MOULDER KNIVES, AUGER BITS AND OTHER CURVED EDGES.

The stones are made in three grades or grits, coarse, medium and fine. The coarse stones are used in machine shops for sharpening very dull or nicked tools, machine knives, and for general use where fast cutting is desired.

Medium stones are for sharpening mechanics' tools in general, more particularly those used by carpenters and in wood-work'ng shops.

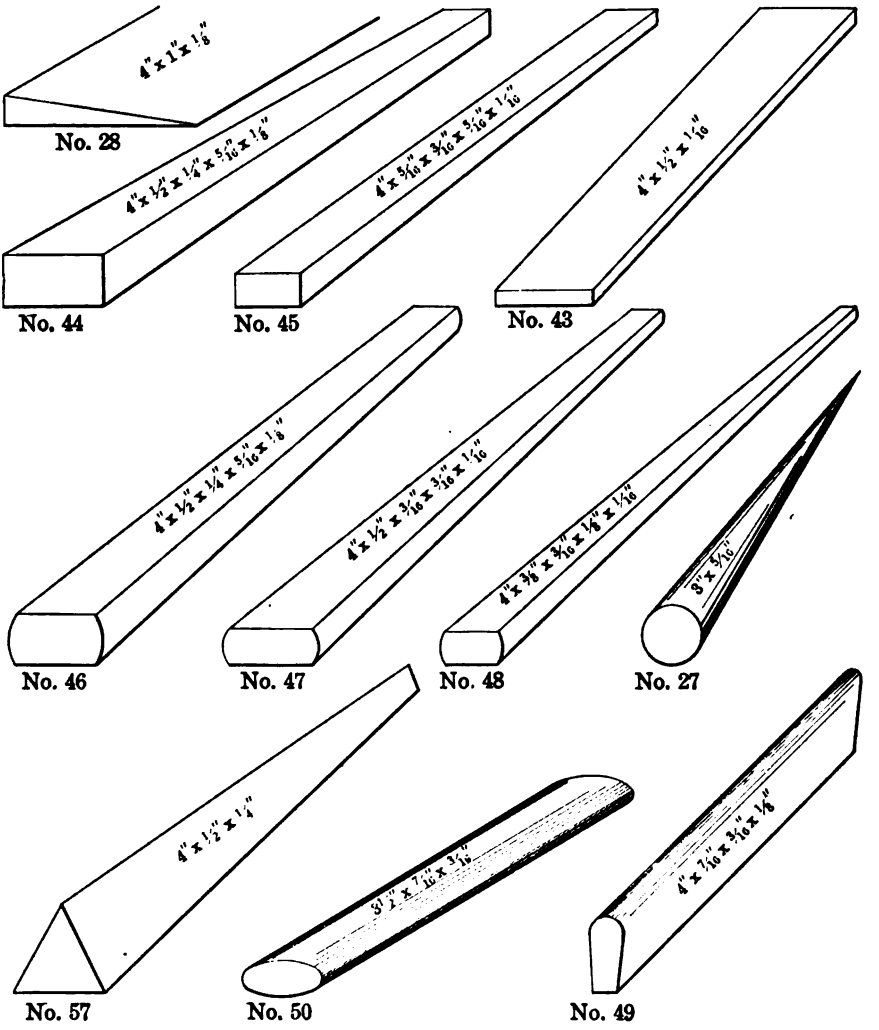


FIG. 286. OILSTONE SHAPES FOR MOLD AND DIE WORK, WATCH- AND CLOCK-MAKER'S TOOLS, ETC.

Fine stones are adapted for engravers, die workers, cabinet makers and other users of tools requiring a very fine, keen-cutting edge.

Of the great variety of shapes and sizes a number adapted especially for machine shop purposes are illustrated full size in Fig. 284. Of these, Nos.

0, 1, 1 1/2, 2, 24 and 29 are for sharpening lathe and planer tools, and for use after grinding; Nos. 23, 25, 56 and 56 1/2 for reamers; Nos. 13, 14 and 15 for taps; Nos. 4, 5, 6, 7, 8, 9, 10, 11, 12 and 26 for dies.

Some shapes and sizes for wood-working tools like gouges, molder knives, auger bits, etc., are shown in Fig. 285. Other shapes for curved-edge wood tools are Nos. 10, 11, 12, 13, 14, 15, in Fg. 284. Shapes for straightedge tools like chisels, plane bits, planer knives, scrapers, paper-cutting knives and other tools with broad flat edges are Nos. 0, 1, 1 1/2, 2, 24, 29, in Fig. 284.

Figure 286 shows some of the sizes and shapes particularly adapted for mold and die work, watch and clock makers' tools, etc. Other shapes suitable for such purposes are shown by Nos. 4, 5, 6, 7, 8, 9 and 26, in Fig. 284 and No. 51 in Fig. 286.

COMBINATION OILSTONES

Combination oilstones range in size from 4 by 1 by 1/2 in. to 8 by 2 by 1 in. The bench sizes are made in two combinations, that is, coarse and medium, and coarse and fine. *Grits and Grinds* in referring to oilstone uses says: There is perhaps no shape of India stone with as wide a range of usefulness as these combination stones in the bench sizes.

Outside carpenters find the coarse side a good substitute for the grindstone and the fine side gives the desired finish on plane irons, chisels, etc. For sharpening planer knives, the 7-in. and 8-in. sizes are particularly useful. This combination stone can be used on knives that a file will not touch.

In paper mills, printing offices and book binderies, they are used for sharpening paper-cutting knives, the No. OO, 8-in. size, being the most desirable. Belt makers use them for sharpening scarfing machine knives, and can makers for sharpening dies.

On scrapers, the coarse side is used when rough scraping is required, and the fine side of the stone where the work is fancy scraping and frosting. If the scraper is sharpened on the fine side no scratches will show after scraping.

Pattern makers find the coarse and fine combination valuable as their trade calls for chisels, plane irons, etc., of a very fine edge. Combination stones are used by piano makers, sash, door and blind workers, and by other wood workers.

Stove makers use them for sharpening ash pan dies.

They are used by tanners and in the shoe factory for sharpening splitting machine knives.

HOW TO CARE FOR OILSTONES[1]

Like anything else, an oilstone can be ruined by wrong treatment and lack of care.

[1]The Pike Manufacturing Company.

There are three objects to be attained in taking good care of an oilstone: first, to retain the original life and sharpness of its grit; second, to keep its surface flat and even; third, to prevent its glazing.

To retain the original freshness of the stone, it thould be kept clean and moist. To let an oilstone remain dry a long time, or expose it to the air, tends to harden it. A new natural stone should be soaked in oil for several days before using. If an oilstone is kept in a dry place (most of them are) it should be kept in a box with closed cover, and a few drops of fresh, clean oil left on it.

To keep the surface of an oilstone flat and even simply requires care in using. Tools should be sharpened on the edge of a stone as well as in the middle to prevent wearing down unevenly, and the stone should be turned end for end occasionally.

To restore an even, flat surface grind the oilstone on the side of a grindstone or rub it down with sandstone or an emery brick.

To prevent an oilstone from glazing requires merely the proper use of oil or water.

The purpose of using either oil or water on a sharpening stone is to float the particles of steel that are cut away from the tool, thus preventing them from filling in between the crystals and causing the stone to glaze.

All coarse-grained natural stones should be used with water. Use plenty of it.

On medium and fine-grained natural stones and on all artificial stones, oil should be used always, as water is not thick enough to keep the steel out of the pores.

To further prevent glazing, the dirty oil should *always be wiped off the stone thoroughly* as soon as possible after using it. This is very important, for if left on the stone, the oil dries in, carrying the steel dust with it. Cotton waste is one of the best things to clean a stone with, and is nearly always to be found in a shop.

If the stone does become glazed or gummed up, a good cleaning with gasolene or ammonia will usually restore its cutting qualities, but if it does not, then scour the stone with loose emery or sandpaper fastened to a perfectly smooth board.

Never use turpentine on an oilstone for any purpose.

CHAPTER XIX

HELPS AND SUGGESTIONS[1]

SELECTION OF WHEEL

Don't believe that all materials can be ground equally well with one and the same wheel.

Get the proper wheel for the work.

Don't expect too much of one wheel.

You would not expect to turn all kinds of lathe work with one tool having only one form of cutting edge. The grinding wheel is a tool for cutting.

Different shapes of work, different kinds of metal, require different cutting edges as well when grinding, as when turning; therefore, different grades and grains of wheels are required for different kinds of work.

Grinding wheels are numbered from coarse to fine, and graded from soft to hard—the grade being denoted by the letters of the alphabet, from E to Z.

Don't attempt to decide on the right wheel without knowing the full details.

Spindle speed and character of the material, shape of work to be ground and surface of wheel in contact are prime factors.

In cylindrical grinding, speed of work, diameter of work and depth of cut must all be reckoned with in the selection of the right combination of grain and grade.

The condition of the machine affects the efficiency of the wheel. Heavy machines with large wheel spindles and massive wheel support call for a different wheel than lighter machines with smaller spindles.

If the work is to be applied by hand that, too, will make a difference.

Your neighbor's conditions are not necessarily your conditions.

Don't order a certain grade wheel merely because that grade is used on similar work in another plant.

Don't use a hard wheel to economize—it is production you are after; big production is economy.

A hard wheel is more apt to change the temperature of the work or to become glazed than a soft one; furthermore, it requires more power to do the same amount of work.

It is a common error, when grinding steel and cast iron, chilled iron and hardened steel, that to produce a fine finish a wheel must be as fine as the surface desired. A coarse wheel will produce a fine finish, if certain facts about grade, depth of cut, speed of work, speed of wheel, etc., are observed.

[1] The Norton Company.

When grinding brass and the softer bronzes, to obtain a finish the wheel must be as fine as the finish required. Bronzes with "manganese" or "phosphor" admit of coarser wheels.

Don't get a wheel made for soft steel for use on hard steel.

For a fine finish on hard stock, a coarse wheel may be necessary and the harder the stock the coarser the wheel.

When ordering, don't forget the diameter, width, style of face, arbor hole, description of work, speed of spindle, and the number and letter denoting the combination of grain and grade, if known.

It is absolutely necessary the maker should know the kind of material to be ground, *i.e.*, whether it is iron—cast, wrought, or malleable—brass composition, hard steel or soft steel, etc., also description of article, so he may judge whether to select a grade suitable for heavy or light work, broad or narrow contact.

The manufacturers make a study of grinding problems and will help you to decide on the grain and grade, if you will furnish the other details.

When reordering, use the previous order number if possible.

The width of the wheel should be in proportion to the amount of the material to be removed with each revolution of the work.

If you reduce the width of the wheel, you must use a finer feed, and consequently do less work.

Don't fail to make a study of the laws governing the use of grinding wheels.

MOUNTING

Never mount wheels without flanges.

Flanges should be, at least, one-third the diameter of the wheel; one-half is recommended—always concaved, never straight or convex.

Use pulp or rubber washers a trifle larger than the diameter of the flanges, or flanges with soft metal facings.

A heavy, rigid machine is a big step toward good results.

Hooded machines are desirable when practicable.

TRUING

Don't start work on a new wheel until you are sure it runs true.

Always have a dresser handy for wheels for off-hand grinding.

Never use a dresser on wheels that grind round work on centers.

For truing wheels used on plain cylindrical and universal grinding machines, cutter and reamer grinders, etc., the diamond is recommended. To obtain the best results it is absolutely necessary.

Never attempt to true a wheel for round grinding without the diamond is held in a rigid tool post on the table of the machine. You cannot do good work with such a wheel when it is trued "by hand."

To get a true surface, you must keep the face of the wheel true.

The quality of surface finish is dependent on the conditions of the wheel face and depth of cut.

SPEED

Don't start to grind until you know the speed is right—not "near enough," but right.

Even a slight variation in speed may be the cause of success or failure of any wheel.

Failure is sometimes turned into success by merely changing the speed of either the wheel or work.

Speed up the spindle as the diameter of the wheel is decreased. Approximately the same periphery rate should be maintained as the wheel wears down.

Complaint is sometimes made that wheels appear to be softer toward the center. Usually this is because the same surface rate of speed is not maintained as the wheel is reduced in diameter. This causes the wheel to wear away faster and appear softer. It is also true that while the grade of the wheel may be uniform throughout, yet the smaller line of contact due to the smaller diameter will cause the wheel to appear softer.

To increase the speed of a grinding wheel gives the effect of a harder wheel; decreasing the speed gives the effect of a softer wheel.

For surface grinding, it is customary to run wheels at a somewhat slower rate of speed than for general grinding. A speed of 4000 to 5000 surface feet is usually employed.

Wheels are run in actual practice from 4000 to 6000 ft. per minute.

Don't expect to get maximum results at a speed of 4500 ft. per minute, if the recommended speed is 6000 ft. per minute.

GENERAL SUGGESTIONS

Transferring a wheel after worn down to a small diameter, from a large machine to a small one, is a good plan.

A variety of grades of wheels can be profitably employed when the amount of grinding will warrant it.

Keep tickets or tags which are sent on the wheels in a record book, so that if a wheel is not satisfactory reference can be made to order number when making complaint. It is equally valuable as a reference when ordering duplicate wheels.

It is best to detail one man to mount and true wheels, adjust rests, oil machines and keep belts in order.

Don't use the wrong wheel on a job because it will require a few minutes time to change wheels. A stop watch will prove to you that changing wheels is cheaper.

There is seldom a case where one and the same wheel can be used on all work without a greater loss of time than the change of wheel would involve. Many times, the time saved in grinding a single piece more than pays for changing the wheel.

A wheel is affected by its treatment.

Don't set aside a wheel as worthless without studying the proposition; it may be just right.

A wheel most suitable on work of very large diameter may wear away too fast on work of smaller diameter.

A suitable wheel for small diameters may cause chatter on pieces of large diameters.

Don't grind round work dry.

A good wheel will grind in water, soda water or oil.

Water keeps the wheel working cool.

Water increases grinding production.

Soda water keeps the work and the machine from rusting.

Oil in soda water, also increases the wheel's effectiveness.

The particles from a grinding wheel do not adhere to steel. Don't let any one convince you to the contrary.

Don't turn a piece of work that can be ground cheaper.

Grinding is profitable for removing stock as well as for finishing.

Don't use a grinding wheel like a piece of cast iron. It is meant for work, but not for abuse.

Keep the face of the wheel true and parallel with axis of spindle.

Vibration makes grinding wheels wear.

Keeps all rests adjusted close to the wheel, otherwise, work is liable to be caught and injury result.

Keep boxes well oiled and adjusted.

When practicable, indicate on each machine the revolution of spindle and size of wheel to be run upon it.

The right wheel is worth many times as much to you as the wrong one.

Don't disregard the setting up instructions that go with the grinding machine.

You are not expected to know everything about grains and grades of wheels. That's the wheel manufacturers' business and they are glad to help you if you will let them.

The men who give the matter of grinding unprejudiced investigation are being rewarded by large returns.

GRINDING POINTERS

The feed should be nearly the width of the wheel the same as in planing with a broad flat tool.

Spring rests are all right for work that is so small that it has less inertia than

the rest. For work that is heavier than the rests, the springs move under the inertia of the work and do not grind as round as solid rests.

The easiest wheel to use is a hard wheel and a narrow face. This can be used with the least care and the least intelligence, but it is the most expensive in every way but the cost of wheels. A wheel as soft as can be run and that is cared for by an intelligent man is the cheapest and best way to grind work.

When there is trouble with the grinding look first to the operator, next to the wheel and lastly to the machine. You will seldom get as far as the machine if you look carefully at the other two and in the order named.

An unbalanced grinding wheel is a prolific cause of chatter marks in the work.

There is no rule that will work for depth of cut. The operator must determine this from his experience for each individual case.

Spiral chatter marks may be due to an unbalanced wheel or a loose spindle.

Watch grinding wheels as they wear down as they are apt to get out of balance as they grow smaller.

The form of the chip which comes from the grinding of metal indicates to a certain extent the temperature at the point of contact with the grinding wheel. If the chips are spherical instead of long and curly, the heat generated by the grinding operation has been excessive. A wheel should be substituted which will cut without heating the work to such an extent. This is not only taking more power than necessary but may be injuring the metal as well. This waste of power and the generation of heat frequently results from using wheels too hard or too fine for the work to be done.

While a wheel made of a combination of a fine grit and a hard bond will last a long time, they are not economical. This combination makes a wheel so dense that there is little opportunity for the cutting particles to project enough to cut and it leaves little room for any chips even if they are cut. Those who endeavor to practice wheel economy to the exclusion of the real economy in grinding, use wheels of this type, and lose money by doing it.

The microscope and the camera are proving a valuable aid to the knowledge of grinding and grinding wheels. They are used both in examining the wheels or abrasives as well as the surfaces ground and a careful examination of both helps the intelligent selection of wheels for specific work to be ground.

The size of the work affects the wheel to be used. A wheel that is a complete success on small work may not give satisfaction on work of large diameter. This is because of the difference in the amount of contact between the wheel and the work.

Wheels for cylindrical grinding should always be trued at the same speed at which they are to run.

Work of large diameter requires a broad or long wheel contact which means a softer wheel than for small work.

It is cheaper to have two or three sizes of pulleys to use as the wheel wears

down than to run the wheel at the wrong speed to save the price of a pulley.

Increasing the speed of a grinding wheel gives the effect of a harder wheel. Decreasing the speed gives the same results as a softer wheel.

When you are dead sure the wheel is right for the work, it is comparatively easy to run down any other troubles that may arise.

Don't guess at the speed of the grinding wheel. A speed indicator is not expensive and is mighty handy in calling a bluff.

Truing a grinding wheel does not necessarily mean sharpening it. In fact, it may dull it unless the work breaks the grains so as to sharpen them. But it makes the wheel true so that it can grind the work perfectly round.

White lead makes a good lubricant for work centers where the load is heavy. Work weighing several tons has been run on centers several hours and the centers were perfectly lubricated at the end of the run.

Always true the wheel between the roughing and finishing cuts if you want the best results.

Revolve the work slower on the finishing than on the roughing cuts.

It isn't economy to use a hard wheel because it does not wear out so fast. The softer wheel will do more work per dollar of cost and that is what counts.

A hard wheel requires more power, is more apt to become glazed and to heat the work, than a soft wheel.

"Loading" is when the material ground off sticks to the wheel and leaves no place for chips.

"Glazing" is when the cutting grit wears down even with the bond and is dull and has no room for chips.

Glass wheels are best for finishing the grinding of granite rolls such as are used in grinding chocolate and similar material.

In grinding copper, brass and the softer bronzes, the finish always depends on the fineness of the grinding wheel.

Feed lines are caused by the lap of the wheel cutting twice on the same portion of the surface. The second passage of the wheel makes a different grain and color in the work but there is usually no measurable difference in diameter.

A coarse wheel will produce a fine finish on any of the harder metals if the grade, the speed of the work and the wheel are right. And it will grind better than the fine wheel into the bargain.

It is estimated that a No. 60 grain wheel of 2-in. face and running at the usual speed, cuts about 400,000,000 chips per minute. They are small but they count up at that rate.

Soft, free cutting wheels can be trued up with a piece of gas pipe, or hard steel, provided the wheel is run at a very low speed. Where wheels are run wet it is better to use running water than to pump the same water on to the wheel over and over again.

Where general grinding is done, wheels will sometimes glaze over. This

can be removed by a dresser, by grinding the edge of sheet steel, and sometimes by reversing the wheel on the arbor, so that the work will come against the opposite side of the grains of emery. A wheel perfectly adapted to its work will not glaze. Wheels newly turned with a diamond will cut better after an hour's use, or by roughing up with a dresser.

The use of lubricating compound in grinding improves the cutting and prolongs the life of the wheel.

It is always best that grinding wheels should be trued with sharp diamonds. Sometimes unsuccessful efforts to obtain a good finish are due to the fact that the grinding wheel was trued with a dull or blunt diamond. When truing, a square holder should not be used. A round holder enables the operator to present a new face of the diamond at any time.

If the spindle on which the wheel is to go is just a little smaller than the hole of the wheel, the wheel will be out of balance unless it is exactly centered which is a very difficult thing to do or have done in the average shop.

The color of a grinding wheel does not affect the cutting quality or the life. The cause of the differences in color in grinding wheels is the difference in color of the bond used in the mixture. Kiln conditions also affect the color to some extent.

It has been shown that a fine wheel can make a fine surface and a coarse wheel can make a coarse surface; but it has never been shown that this must follow. In grinding chilled iron for example, on rolls 10 in. diameter and 14 ft. long we can make a mirror finish with a No. 10 wheel if we grind slow enough. If we should use a fine wheel on this work we would leave nothing but fine scratches.

It is known that scratches are caused many times by some of the material ground off the piece adhering to the wheel, whether or not the wheel is coarse or fine.

When there is no room for the chips, the grinding wheel loads, provided the wheel is strong enough so that the cutting grains do not break out.

In most cases of complaints on wheels being out of true, it is caused by the wheel having been forced on the arbor on the spindle and naturally with uneven side pressure. The hole is put out of line enough to cause the wheel to run out sideways even after tightening the nut. This is very easy to remedy, simply loosen and tighten the nut a few times with a turning of the wheel, thereby, forcing the hole in line again. The cause of this may be due to the spindle being over-size although, of course, this is always denied by the customer.

To examine the condition of a ground hole don't look through it. Let the light shine into it, but look down into it at as near right angles to the hole as possible.

Grinding holes having keyways or slots tend to keep the wheel sharp and prevent glazing. Striking the edge of the slot seems to true and sharpen the grinding wheel.

Accurate cylindrical grinding can only be secured by having both the grinding wheel spindle and the work revolving in bearings that are true and without lost motion.

Ball bearings have not been successful for spindle bearings on slow running wheels, both on account of play between the balls and races and the difficulty of securing absolutely concentric ball races.

Thrust bearings that control the end movement of adjustment screws, should be ground as accurately as possible. Any variation in thickness or eccentricity, tells directly on the work. If ball bearings are used extraordinary care must be taken to have every ball of exactly the same diameter.

With form grinding, where the wheel is fed straight into the work, there is a more even wear on the wheel and by careful handling the shape can be retained much longer than might be supposed.

While such intricate shapes as are obtained with formed milling cutters are not attempted with grinding wheels, considerable work is being done which requires fillets and rounds of considerable accuracy. These retain their shape because of the many cutting points which are presented to the work each minute, making only a small amount of wear on each point. Then, too, they are being constantly sharpened by points breaking away with fair uniformity over the whole grinding surface and require shaping with the diamond much less than might be imagined.

There is almost no limit to the size of work which can be ground by feeding straight in with a formed wheel. It is simply a question of power and the stiffness of the machine.

As a rule, the greatest economy is obtained by the combination of grinding with very rough turning. Yet there are cases where the least expensive way is to grind direct without turning.

A modern grinding wheel used on a modern machine by an operator with a good knowledge of grinding is just as surely a milling cutter as if it were made of steel. Its cutting surface consists of millions of small sharp-cutting teeth and each tool that comes in contact with the work cuts off a chip in the same manner as the tooth of a milling cutter.

By merely changing the speed of either the wheel or work, failure is sometimes turned into success. Even a slight variation in speed may make this difference. If grinding-wheel users would stop and consider that each particle or grain of abrasive is called upon to do more work as the grinding wheel is reduced in diameter he would not declare that the wheel is softer near the center because it wears faster.

Some of the things to be considered in selecting wheels are: The sizes of grains and the tensile strength of the bonding that is to be ground; the tensile strength or hardness necessary to withstand the vibrations brought about from mechanical defects in design of the machine on which the wheel is to be mounted;

contact—whether broad, narrow, long or short—between the wheel and work; speed of wheel and work, and sometimes other conditions.

A great variety of combinations of grain and grade is required in surfaee grinding. Variation in sizes and shapes of pieces to be ground makes it necessary to vary the combinations of grain and grade of grinding wheels in order to get the best results.

WHEELS USED ON DIFFERENT KINDS OF WORK

Aluminum, brass and bronze on vertical machine used elastic wheels 30, grade 1 1/2.

Aluminum castings—an elastic wheel 46-3.

Brass castings—elastic wheel, 12×1/2 in. 60-3, is used for roughing out brass castings, running at 1600 r. p. m. Silicate wheels 30-0 and vitrified 46-0 are also used.

Brass composition letters. Silicate wheel 5 7/8×3/8-in. cylinder with 1 1/4-in. rim, 46-L.

Bronze bushings—silicate wheel, 60-M.

Burrs from boiler plate use alundum 36-R.

Cast iron, cylindrical grinding—silicate 30-J.

Celluloid combs ground free-hand with 12×2 in. 46-G. wheels instead of wooden wheels covered with sand-paper. Run wheel at slow speed. If oil is rubbed on the face of the wheel the work has a better finish.

Chilled car wheels—wheels from 12 to 18 in. of 20-Q does good work.

Chilled iron blocks—a 30-N wheel, 12×1 1/2×1 1/4 in. at 1900 r. p. m. on automatic surface grinder, making six movements each way per minute ground 6×12-in. chilled cast-iron blocks for over 6 months.

Cold rolled steel shaft, 1 1/8 in. diameter, ground with 24-L wheel.

Carbon shaft, .30 point, ground with same wheel.

Cutting off saws—alundum wheel 8×1/2×1 in. D face, 60-P is being used for cutting off saws.

Dry grinding of heavy lathe and planer tools is being advocated for high-speed tools. Use 16-Q and 20-P wheels.

Files—cup wheel 12-in. rim, 1 3/8 in. thick, on Pratt & Whitney vertical used for grinding file blanks. 20-H silicate.

Flat irons are ground dry, free hand with 36-P wheels, about 18×3-in. wheels being used.

For grinding dies with a wheel on a flexible shaft, 2×3/8 in. 50-U 1×3/16 in. 100-Q wheels do good work.

Gray-iron castings can be polished nicely with 20-R silicate wheel at about 6000 ft. per minute.

Hard and soft plates. Alternate hard and soft plates were ground off at the same time by a 18×2 1/2×1 9/16 in. 16 grade P wheel.

Hardened cams for automobile work. Both 46-M and 46-N alundum wheels used, N is best. Wheel 2000 r. p. m., work 100 r. p. m., Landis grinder using water.

Hardened steel—use 24-K alundum wheel.

Hardened or high-speed steel on vertical or end grinders—use 30-H vitrified wheels.

Heavy steel or malleable castings—use open porous wheels of coarse grain. Alundum wheels 16-S vitrified have given good results.

Holes in glass—alundum wheel 54.

Knives, pocket—silicate wheels 40×3 1/2 in., 120-0 used for pocket knives in competition with sand stones. One wheel was used 18 months and ground 223,392 blades.

Elastic wheel—12×3/16 in. B face, 70-5 used for "choiling" pocket knife work.

Locomotive guides—silicate wheel 30-L.

Malleable iron, small pieces such as saddlery hardware, alundum 20-S.

Larger work, also unannealed cast iron, 20-Q.

Manganese steel—best results obtained with very coarse wheels.

Manganese steel rails, switches, etc. are ground dry on a planer type machine with 12×3 in. 20-N wheel. When these must be ground with a swing-frame grinder, use a 14-R wheel, about 16×2 in.

Polishing steel forgings—alundum grain 46 on convas wheels.

Purse clasps and similar work can be ground free hand with a 60-Q wheel.

Razors are finished, not dug out, by free hand dry grinding, with either 2×1 1/4 or 3×1 1/4 in., vitrified wheels, 100-J.

Razor blades, safety—automatic machine for grinding safety razor blades uses 5×1/2-in. alundum elastic wheel, 150-3 for first bevel and XF-3 for finish bevel. Also a vitrified wheel of razor hone material for honing.

Safety razor blades—wheel of razor hone 5 in. ×1/2-in. material and run very slowly, used in automatically honing razor blades.

Rifle barrels—alundum wheels, 60-L and 46-M were found satisfactory.

Rubber, soft for typewriter rolls—alundum wheels 3×1/4 in. 46-H.

Sapphires and other precious stones are ground free hand, wet, with 10×1 in. 150-P wheel.

Shoe heels—cup wheels 20-N, speed 1200 r. p. m.

Small drills—alundum wheels 60-0 do good work.

Springs—heavy coil springs, 24×4-in. alundum, 12-R.

Automobile gear springs, ground by hand, alundum 24-0.

Torpedo flasks—a silicate wheel, 24-J 30×3×14 in. on Landis machine grinds 30-in. torpedo flasks in 20 minutes.

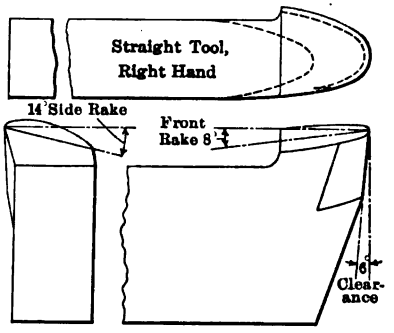
Wet grinding of high-speed tools use 24-P silicate wheels.

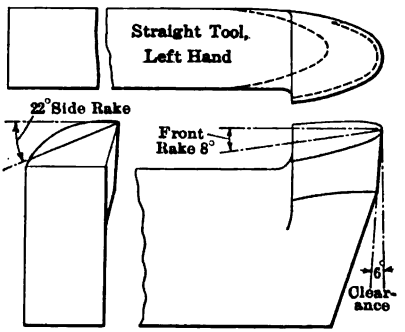
ROUND NOSE ROUGHING TOOLS FOR LATHES AND PLANERS

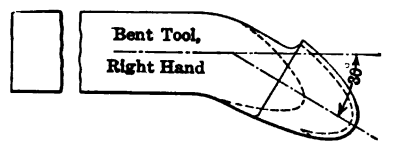
BLUNT TOOLS FOR CAST IRON AND HARDER GRADES OF STEEL (14° SIDE RAKE)
SHARP TOOLS FOR WROUGHT IRON AND SOFTER GRADES OF STEEL
(22° SIDE RAKE)

	Right hand				Left hand				
	Straight face		Bent			Straight face		Bent	
Face	Horizontal angle on machine	Vertical angle on machine	Horizontal angle on machine	Vertical angle on machine	Face	Horizontal angle on machine	Vertical angle on machine	Horizontal angle on machine	Vertical angle on machine
Top	Blunt 97.75°	Blunt 104°	Blunt 103.7°	Blunt 98.3°	Top	Blunt 97.75°	Blunt 76°	Blunt 103.7°	Blunt 81.7°
	Sharp 97.4°	Sharp 112°	Sharp 107.3°	Sharp 105.6°		Sharp 97.4°	Sharp 68°	Sharp 107.3°	Sharp 74.4°

End face of these tools is ground by using a former and making horizontal angle of adjustment 96°







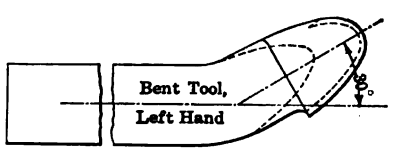


TABLE 34.—STANDARD SHAPES AND ANGLES OF LATHE AND PLANER TOOLS—SELLERS SYSTEM

LATHE

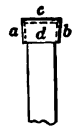
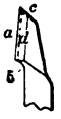
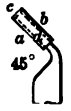
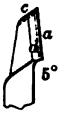
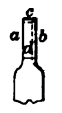
Kind of tool	Face	Clearance	Horizontal angle on mach.	Vertical angle on mach.
Finishing 	Side a	4°	90.5°	356°
	Side b	4°	90.5°	184°
	End c	6°	84°	90°
	Top d	15°	105°	90°
Nicking	Side a	3°	90.5°	357°
	Side b	3°	90.5°	183°
	End c	6°	84°	90°
	Top d	1°	91°	90°
Side, Right 	Side a	6°	85°	353.95°
	End c	6°	54.5°	10.4°
	Top d	12°	91.05°	102.05°
Bent side Right	Side a	6°	45.3°	351.55°
	End c	6°	75.1°	186.2°
	Top d	12°	98.45°	98.55°
60° V Thread Right	Side a	12°	60.7°	346.2°
	Side b	7°	60.25°	188.15°
	End c	15°	75°	90°
	Top d	0°	90°	90°
Square thread Right	Side a	10°	90°	350°
	Side b	0°	90°	180°
	End c	6°	84°	90°
	Top d	0°	90°	90°
Bent finishing Left	Side a	4°	135.35°	354.4°
	Side b	4°	45.65°	185.6°
	End c	6°	45.3°	351.55°
	Top d	15°	100.51°	100.71°
Bent nicking Left 	Side a	3°	135.4°	355.7°
	Side b	3°	45.6°	184.2°
	End c	6°	45.3°	351.55°
	Top d	1°	90.7°	90.7°
Side, Left 	Side a	6°	85°	186.05°
	End c	6°	125.5°	349.6°
	Top d	12°	91.05°	77.95°
Bent side, Left	Side a	6°	44.7°	8.45°
	End c	6°	75.1°	353.8°
	Top d	12°	98.45°	81.45°
60° V Thread Left	Side a	7°	60.25°	351.25°
	Side b	12°	60.7°	193.8°
	End c	15°	75°	90°
	Top d	0°	90°	90°
Square thread Left 	Side a	0°	90°	0°
	Side b	10°	90°	190°
	End c	6°	84°	90°
	Top d	0°	90°	90°

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TABLE 35.—STANDARD SHAPES AND ANGLES OF LATHE TOOLS—SELLERS SYSTEM

LATHE

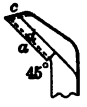
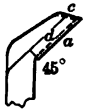
Kind of tool	Face	Clearance	Horizontal angle on mach.	Vertical angle on mach.
Bent finishing Right	Side a	4°	45.65°	354.4°
	Side b	4°	135.35°	185.7°
	End c	6°	45.3°	188.45°
	Top d	15°	100.51°	79.31°
Bent nicking Right	Side a	3°	45.6°	355.8°
	Side b	3°	135.4°	184.3°
	End c	6°	44.7°	8.45°
	Top d	1°	90.7°	89.3°
Bent brass Right	Side a	10°	45.85°	346°
	Side b	6°	95°	186°
	End c	10°	50.7°	193.3°
	Top d	0°	90°	90°
Inside bent Left 	Side a	6°	134.7°	351.55°
	End c	6°	106.1°	337.9°
	Top d	12°	81.55°	98.55°
60° V Thread Bent, Right	Side a	12°	109.1°	320.6°
	Side b	7°	104.9°	187.25°
	End c	15°	43.1°	20.75°
	Top d	0°	90°	90°
Square Thread Bent, Right	Side a	10°	45.9°	346°
	Side b	0°	135°	180°
	End c	6°	44.7°	8.45°
	Top d	0°	90°	90°
Brass	Side a	10°	70.3°	349.4°
	Side b	6°	70.1°	186.4°
	End c	10°	63.2°	22.65°
	Top d	0°	90°	90°
Inside bent Right 	Side a	6°	134.7°	188.45°
	End c	6°	73.9°	22.1°
	Top d	12°	81.55°	81.45°
60° V Thread Bent, Left	Side a	7°	106.5°	334.6°
	Side b	12°	104.7°	192.4°
	End c	15°	43.1°	20.75°
	Top d	0°	90°	90°
Square Thread Bent, Left	Side a	0°	45°	0°
	Side b	10°	134.1°	194°
	End c	6°	44.7°	8.45°
	Top d	0°	90°	90°

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TABLE 35.—STANDARD SHAPES AND ANGLES OF LATHE TOOLS—SELLERS SYSTEM—*Continued*

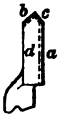
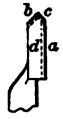
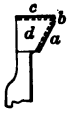
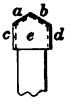
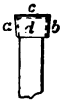
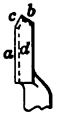
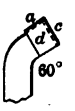
	Kind of tool	Face	Clearance	Horizontal angle on mach.	Vertical angle on mach.	Kind of tool	Face	Clearance	Horizontal angle on mach.	Vertical angle on mach.	
PLANER	Finishing	Side a	3°	90.5°	357°	Splining	Side a	2°	90.5°	358°	PLANER
		Side b	3°	90.5°	183°		Side b	2°	90.5°	182°	
		End c	4°	86°	90°		End c	4°	86°	90°	
		Top d	7°	97°	90°		Top d	3°	93°	90°	
	Side finishing Right	Side a	6°	90°	354°	Side finishing Left	Side a	6°	90°	186°	
		Side b	4°	85°	356°		Side b	4°	85°	184°	
		End c	6°	69.15°	17.1°		End c	6°	110.85°	342.9°	
		Top d	18° 5°	85.25°	108°		Top d	18° 5°	85.25°	72°	
	30° Angle Right 	Side a	6°	90°	186°	30° Angle Left	Side a	6°	90°	354°	
		Side b	4°	120.2°	352°		Side b	4°	59.8°	8°	
		End c	4°	60.1°	184.6°		End c	4°	60.1°	355.4°	
		Top d	0°	90°	90°		Top d	0°	90°	90°	
	Bent finishing Right 	Side a	3°	120.6°	354.1°	Bent finishing Left	Side a	3°	59.4°	5.9°	
		End c	4°	60.1°	184.6°		End c	4°	60.1°	355.4°	
		Top d	7°	93.5°	83.9		Top d	7°	93.5°	96.1°	
	Chamfering 	Side a	4°	45.15°	354.3°	45° Angle slot Right and Left	Side a	4°	135.15°	354.35°	
		Side b	4°	44.85°	5.65°		Side b	4°	134.85°	185.65°	
		Top d	0°	90°	90°		Side c	4°	90°	356°	
							Side d	4°	90°	184°	
							End e	4°	86°	90°	
							Top f	0°	90°	90°	
SLOTTER	Corner	Side a	4°	94°	95°	Square 	Side a	4°	94°	180°	SLOTTER
		Side b	4°	94°	355°		Side b	4°	94°	0°	
		End c	7°	83°	45°		Side c	4°	94°	90°	
							Side d	4°	94°	270°	
							End e	0°	90°	90°	

TABLE 36.—STANDARD SHAPES AND ANGLES FOR PLANER AND SLOTTER TOOLS—SELLERS SYSTEM

	Kind of tool	Face	Clearance	Horizontal angle on mach.	Vertical angle on mach.
PLANER	Cutting down Left 	Side a	6°	90°	186°
		End c	4°	100.8°	338.1°
		Top d	0°	90°	90°
	Bent side finishing Left	Side a	6°	45.3°	188.45°
		Side b	4°	40.2°	186.2°
		End c	6°	65.15°	353.35°
		Top d	18° 5°	99.3°	73.75°
	40° Angle Left 	Side a	6°	90°	186°
		Side b	4°	40.2°	353.8°
		End c	4°	39.9°	5.2°
		Top d	0°	90°	90°
	45° Angle Left 	Side a	6°	90°	186°
		Side b	4°	45.15°	354.35°
		End c	4°	44.85°	5.65°
		Top d	0°	90°	90°
	30° Angle slot Left	Side a	4°	119.9°	184.6°
		Side b	4°	90°	184°
		End c	4°	86°	90°
		Top d	0°	90°	90°
SLOTTER	Splining	Side a	0.3°	90.3°	359.7°
		Side b	0.3°	90.3	180.3°
		End c	3°	87°	90°
		Top d	4°	94°	90°

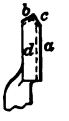
	Kind of tool	Face	Clearance	Horizontal angle on mach.	Vertical angle on mach.
PLANER	Cutting down Right	Side a	6°	90°	354°
		End c	4°	79.2°	21.9°
		Top d	0°	90°	90°
	Bent side finishing Right	Side a	6°	45.3°	351.55°
		Side b	4°	40.2°	359.8°
		End c	6°	65.15°	186.65°
		Top d	18° 5°	99.3°	106.25°
	40° Angle Right 	Side a	6°	90°	354°
		Side b	4°	49.8°	6.2°
		End c	4°	50.1°	354.8°
		Top d	0°	90°	90°
	45° Angle Right	Side a	6°	90°	354°
		Side b	4°	44.85°	5.65°
		End c	4°	45.15°	354.35°
		Top d	0°	90°	90°
	30° Angle slot Right	Side a	4°	119.9°	355.4°
		Side b	4°	90°	356°
		End c	4°	86°	90°
		Top d	0°	90°	90°
SLOTTER	Hexagon For wrenches	Side a	4°	120.2°	352°
		Side b	4°	59.8°	8°
		Side c	4°	90°	356°
		Side d	4°	90°	184°
		Top e	0°	90°	90°

TABLE 36.—STANDARD SHAPES AND ANGLES OF PLANER AND SLOTTER TOOLS—SELLERS SYSTEM—*Continued*

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